CALIFORNIA CENTER FOR INNOVATIVE TRANSPORTATION

IN COLLABORATION WITH

ASE CONSULTING LLC AND
R.C. ICE AND ASSOCIATES

FINAL REPORT

SYSTEMS ENGINEERING EVALUATION FOR ITS

UNIVERSITY OF CALIFORNIA

SUBAGREEMENT SA4645

CALIFORNIA DEPARTMENT OF TRANSPORTATION

INTERAGENCY AGREEMENT 51A0255, TASK ORDER 11

JUNE 15, 2006

Executive Summary

This is the final report for the "Systems Engineering Evaluation for ITS Projects" study. This final study report includes evaluation results, a systems engineering model that has been adapted so it fits with the existing Caltrans project development process, and a series of recommendations for how to implement the systems engineering approach within Caltrans

The Strategic goal and objectives that guided this study were:

> ***Long Range Goal:*** Implement Systems Engineering best practices and capabilities for Intelligent Transportation Systems Projects within Caltrans and integrate these best practices and capabilities within the existing Project Development Process.
>
> ***Primary Objective:*** Document and implement best practices in systems engineering for ITS projects and at a minimum meet the 23 CFR 940 part 11 of the FHWA Final Rule on the application of the systems engineering analysis for ITS projects.
>
> ***Secondary Objective:*** Evaluate the benefit of the recommended Systems Engineering Processes for ITS to other system development processes within the department.

Data Collection

The Consultant team obtained and reviewed over 100 documents as part of this effort. In addition to the Project Development Procedures Manual (the "Gold Book"), many key documents were collected from each division that provided real insight into the Caltrans Project Development Process. A significant number of the documents are available from the Caltrans website and many additional documents were identified during the interviews and passed along by interview participants. The task 2 interim report includes a complete list of the documents that were collected, sorted by the Division that provided the document.

The Caltrans coordinator did an excellent job of making a range of domain experts from the department available for interviews. Interviews were conducted with thirteen (13) Divisions, three (3) Districts, key offices, individual experts, and five (5) follow-up interviews. The interviews were critical to the data collection effort since they allowed the consultant team to move beyond the documents and learn first-hand how the project development process really works within Caltrans. The interviews provided valuable context for the documentation review, affirming the documented process and providing information on the roles and responsibilities of each of the divisions at headquarters and in each of the districts. A complete list of interview participants and a comprehensive set of interview notes is included in the task 2 interim report.

General Observations

The documentation review and expert interviews resulted in a number of key observations on the application of systems engineering for Capital, IT, and ITS projects:

1) For capital development projects, the principles of systems engineering have been practiced for many years and the maturity of these practices is very high. The project development processes are well documented and followed.
2) For information technology projects, the application of systems engineering is still developing and processes are currently being documented. Due to the relative immaturity of the process, few completed project artifacts were available for review. The Department is currently aligning the IT project development process so that it supports the DOF project oversight requirements defined in the State Acquisition Manual (SAM).

3) For ITS projects, the application of systems engineering is in the very beginning phases. There is an awareness of the need for a systems engineering process, but few examples of good systems engineering practice were identified. There are pockets of excellence and in general, the quality of people that are involved in project development are excellent. Currently, systems engineering processes have not been documented specifically for ITS project developments, but a number of systems engineering practices are being performed within the department at different levels of the organization.

During the interviews and data collection effort, it became clear that organizational relationships, both within the department and between the department and other agencies, are critical to successful ITS project development. Developing productive working relationships were some of the most formidable challenges identified during the interviews. For Capital development projects, the key relationships and organization roles and responsibilities have been well established. For ITS Developments, these relationships should be expanded to include a closer tie to the Division of Information Technology and the Department of Finance.

Systems Engineering Process Requirements

While the FHWA systems engineering analysis requirements provided the initial impetus for this study, there are a number of process-related requirements that apply to ITS projects that are levied by other federal and state agencies, in addition to FHWA. Since ITS projects are so varied, ranging from field equipment procurement through major system integration and software development projects, different requirements will apply to different projects. As shown in Figure 5, ITS projects may be subject to requirements associated with the Capital Development process as well as the IT project development process. ITS projects have been deemed by the Legislature as IT projects and are subject to the same SAM requirements.

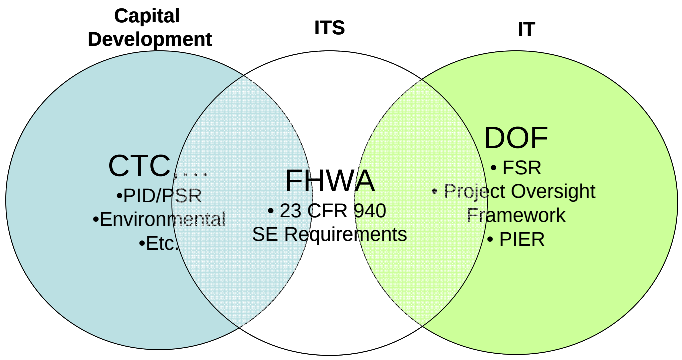

Figure 1: ITS, IT, and Capital Development Process Requirements

The systems engineering process that is developed must be tailorable so that it applies to widely varied projects that are subject to different requirements. The ultimate objective is a single tailorable process and set of deliverables that satisfies all of the process-related requirements levied on the Department for ITS projects ranging from simple signal systems to highly complex ITS projects like CATMS.

Systems Engineering Model

A life cycle model that integrates the systems engineering approach into the Caltrans project development process is shown in Figure 12. This model addresses the FHWA 23 CFR 940 systems engineering requirements as well as the process requirements for IT projects that are levied by the SAM. The model is based on the model developed for the Department in the Systems Engineering Guidebook for ITS project Version 1.9. This initial model was updated based on the detailed evaluation of the Caltrans processes that was performed for this project.

Recommendations

Beneficial implementation of the systems engineering approach depicted in Figure 2 requires a documented process, organizational support, skilled personnel, and appropriate resources and tools. This report includes a series of recommendations that addresses each of these aspects of process improvement. The recommendations are divided into 3 sections:

1) Systems engineering capability enhancements and process improvements
2) Organizational enhancements to create an environment for systems engineering to work
3) Integrate the activities of traditional capital projecs and ITS projects together.

These recommendations build on initial steps that the department has already taken in systems engineering process improvement. For example, the Intelligent Transportation Systems Interdepartmental Coordination agreement, signed by most divisions and the District 4 director, provides critical management support and visibility for the recommended process and capability improvements. It is the foundation for the departmental policy, organizational enhancements and allocation of responsibilities, process definition and integration, and staff capacity building that are recommended in this study. The Department has also already implemented systems engineering training and the Caltrans Systems Engineering Guidebook for ITS.

Process Improvements and Capability Enhancements

The following recommendations were identified to improve the systems engineering process and capabilities for ITS projects within Caltrans.

1) Review, refine, and adopt a systems engineering life cycle model, beginning with the recommended systems engineering model identified in Figure 2.
2) Establish Department policies and a documented systems engineering process for ITS project development, building on existing processes and the systems engineering lifecycle model. Implement the documented systems engineering processes in a phased approach that leverages the IT process development effort whenever possible. The processes should be initially piloted in selected projects and lessons learned should be used to improve the documented processes, prior to full-scale implementation across the organization. For example, the CATMS project is being developed using a systems engineering process. Also, District 7 has established an integrated team approach to ITS project development.
3) Establish an ITS Academy that will include systems engineering and ITS project management elements. This has to potential to be a model for other states and could be premiere center for training ITS and systems engineering and project managers in ITS.

Organizational Enhancements

Organizational enhancements will provide an environment for systems engineering to mature and to improve over time. The organizational enhancements will address one of the most important keys to success – management support for system engineering. The organizational recommendations are:

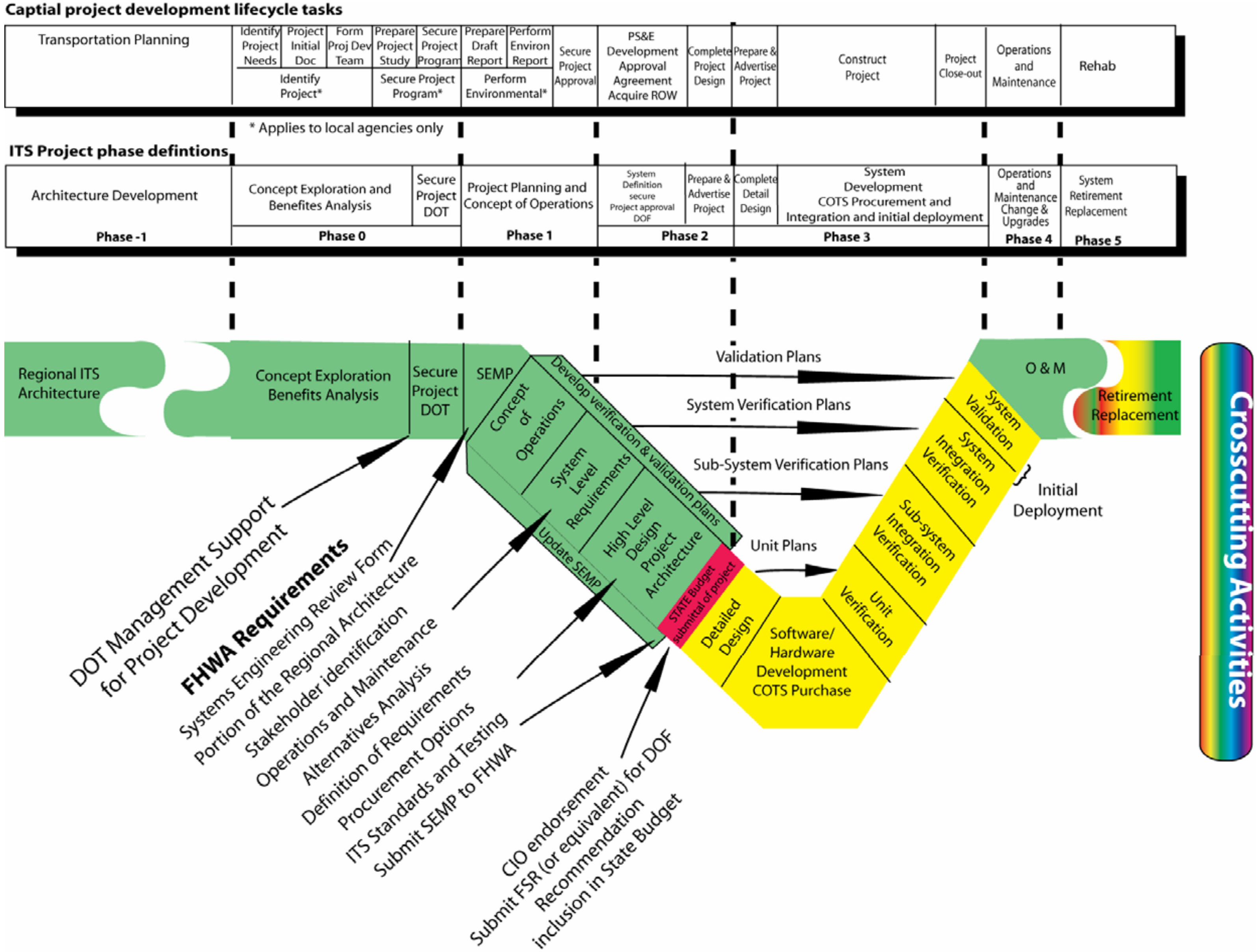

Figure 2: Caltrans Integrated Systems Engineering Lifecycle Model

1) Establish policies and key initial management processes including configuration management, risk management, systems engineering management planning, etc. Utilize existing PMI-based policies and processes already established by the Project Management Division.
2) Establish a systems engineering organization that has a focus on ITS processes across the Department. This could be a standing committee that represents the existing organizations that are involved with ITS and has the authority to implement process change.
3) Establish an ITS technology center – Create a forum for the discussion of technologies with ITS practitioners from around the state. (Phase 3) – This would allow the key ITS technologist to work together and collaborating on ITS technology, standards, and other key issues.
4) Establish an on-line systems engineering repository that includes systems engineering directives, best practices, templates, processes, guidebooks, case studies and tools (such as requirement management, modeling, and decision support tools). The repository would be a resource that project managers and project systems engineers could access and use.(phase 1-3)

Integration Recommendations

The following initial steps are recommended to integrate systems engineering into the capital development process. Refer to Figure 2 to see the ITS project phases that are referenced here.

1) Extend the existing project development team concept to form integrated teams for ITS projects at the beginning of Phase 0, using District 7's approach as a starting point. Include Information Technology, Maintenance, ITS and Systems Engineering expertise.
2) Perform Phases 0-2 of ITS project development as part of the capital development process, funded through the STIP/SHOPP. ITS Field element projects would continue through the capital development process and the ITS Application development would proceed until the end of phase 2.
3) Use the artifacts that are developed in phases 0 through 2 to develop the FSR for ITS applications. Coordinate an agreed-to format with DOF that supports DOF oversight requirements using artifacts that are natural by-products of the Caltrans process.
4) Involve the FHWA ITS staff in the Concept phase and then at the decision gates for phases 0-3.

Note in particular that the FSR would be developed after the studies and analyses in Phases 0-2 are performed since studies and analyses can be performed without involvement of DOF or securing funds through the FSR process. Using this approach, the process is under the control of the Department while the basic systems analyses are performed.

Next Steps

The evaluation results, systems engineering model, and recommendations that are identified in this final report should be broadly reviewed and revised as necessary to ensure they reflect the vision of the Department. The agreed to plan should be reviewed and coordinated with FHWA and other agencies to ensure that all parties support the plan. Many studies have shown the importance of using a systems engineering approach, but the approach must be implemented so that it fits with the way the Department does business.

Final Report

SYSTEMS ENGINEERING EVALUATION FOR ITS

1 Introduction

This is the final report for the "Systems Engineering Evaluation for ITS Projects" project. Through this project, the Department is assessing how well it is performing systems engineering on Intelligent Transportation Systems Projects. The project supports the overall objectives of the department:

Project Strategic Goals and Objectives

> ***Long Term Goal:*** Implement Systems Engineering best practices and capabilities for Intelligent Transportation Systems Projects within Caltrans and integrate these best practices and capabilities within the existing Project Development Process.
>
> ***Primary Objective:*** Document and implement best practices in systems engineering for ITS projects and at a minimum meet the 23 CFR 940 part 11 of the FHWA Final Rule on the application of the systems engineering analysis for ITS projects.
>
> ***Secondary Objective:*** Evaluate the benefit of the recommended Systems Engineering Processes for ITS to other system development processes within the department.

This report builds on the interim task report produced at the conclusion of Task 2. It provides evaluation results, a systems engineering model that has been adapted so it fits with the existing Caltrans project development process, and a series of recommendations for how to implement the systems engineering approach within Caltrans as shown in Figure 7.

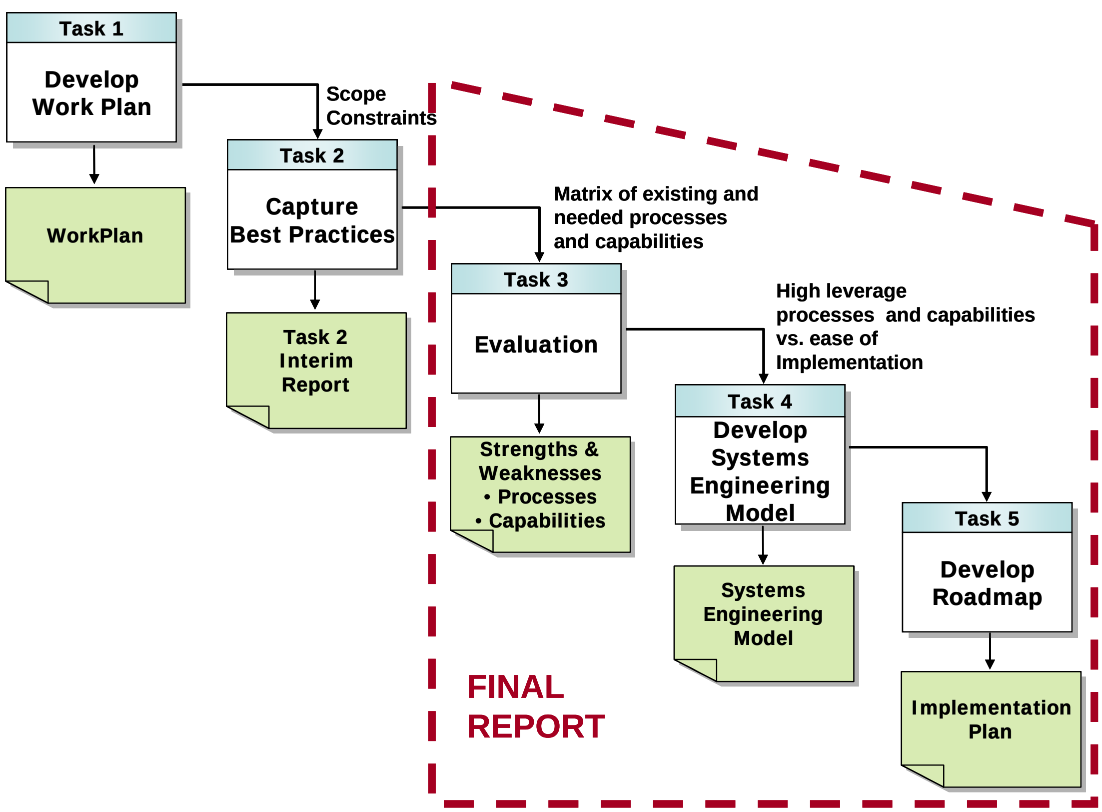

Figure 1 Project Approach

1.1 The Benefits of Systems Engineering

What every ITS project manager wants is a successful system at the end of the project, where "success" is measured by:

1. how well the system satisfies the needs of the people who use it.
2. the cost and schedule performance of the project

The primary benefit of doing systems engineering is that it will reduce the risk of schedule and cost overruns and increase the likelihood that the system will meet the user's needs. Other benefits include:

- better system documentation
- higher level of stakeholder participation
- system functionality that meets stakeholders' expectations
- shorter project cycles
- systems that can evolve with a minimum of redesign and cost
- higher level of system reuse
- more predictable outcomes from projects

Many studies have shown the importance of using systems engineering principles. Better systems engineering has been correlated with shorter project schedules and lower development costs. Perhaps the most frequently cited report, and one that is based on a broad cross-industry survey of more than 250,000 IT projects, is the Standish Group Chaos Report (published in 1994 and 2000). Other more focused studies have been performed by the International Council of Systems Engineering (Eric Honour, "Understanding the Value of Systems Engineering", 2004.), and Boeing (John D. Vu. "Software Process Improvement Journey: From Level 1 to Level 5"). IBM (IBM Commercial Products, Bruce Barker) also did an interesting analysis in 2003 that determined that incorporating systems engineering practices into their organization – through organizational changes, process documentation, and training – substantially improved their project development efficiency. As shown in Figure 3, the IBM study indicated that adopting systems engineering cut their project costs per "point" (a standard complexity measure used at IBM) in half from 2000 (no systems engineering) to 2002 (systems engineering fully implemented). Unfortunately, we don't have enough experience with systems engineering for ITS to have amassed solid quantitative proof for ITS projects - yet.

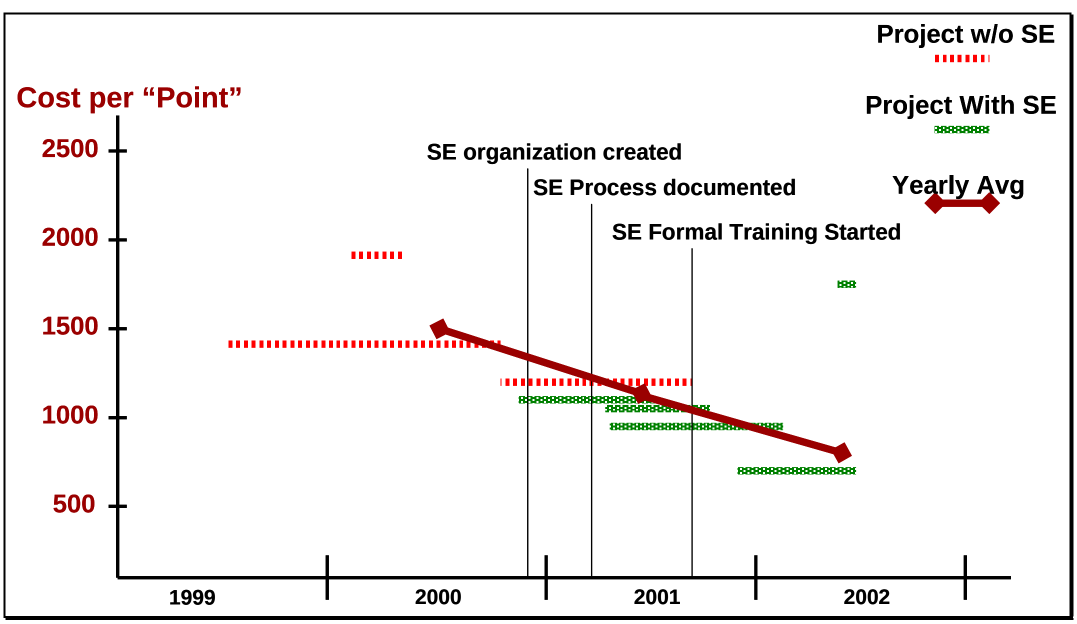

Figure 3: Systems Engineering Yields Productivity Improvements at IBM (© IBM Corp 2003)

1.2 A Few Definitions

This final report and, in fact, the entire project, relies on a shared understanding of a few key terms. In this project, the consultant team will perform an evaluation of the *systems engineering process* and *capabilities* that are used by Caltrans for ITS projects. The definition for Systems Engineering that we use was developed by the International Council of Systems Engineering (INCOSE). The definition goes beyond the specific requirements in FHWA Rule 940.11 to provide a more comprehensive view of systems engineering's application to systems development.

What is Systems Engineering?

"Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem:

- Operations
- Cost & Schedule
- Performance
- Training & Support
- Test
- Disposal
- Manufacturing

Systems Engineering integrates all the disciplines and specialty groups into a team effort forming a structured development process that proceeds from concept to production to operation. Systems Engineering considers both the business and the technical needs of all customers with the goal of providing a quality product that meets the user needs."
(from INCOSE - http://www.incose.org/practice/whatissystemseng.aspx)

What is an ITS Project?

In order to apply systems engineering to ITS projects and satisfy the Code of Federal Regulations, Chapter 23, Section 940 (23 CFR 940), it is important to define "ITS Project". 23 CFR 940 defines ITS projects quite broadly:

> *ITS Project* means any project that in whole or in part funds the acquisition of technologies or systems of technologies that provide or significantly contribute to the provision of one or more ITS user services as defined in the National ITS Architecture.

This definition encompasses a wide range of projects. Smaller ITS projects might be limited to purchase and installation of field equipment – controllers, ramp meters, signals, etc. Larger ITS projects support integration of multiple systems and development of custom software – for example, CATMS and 511 system developments. These varied ITS projects overlap with traditional capital development projects and IT projects, as shown in Figure 4.

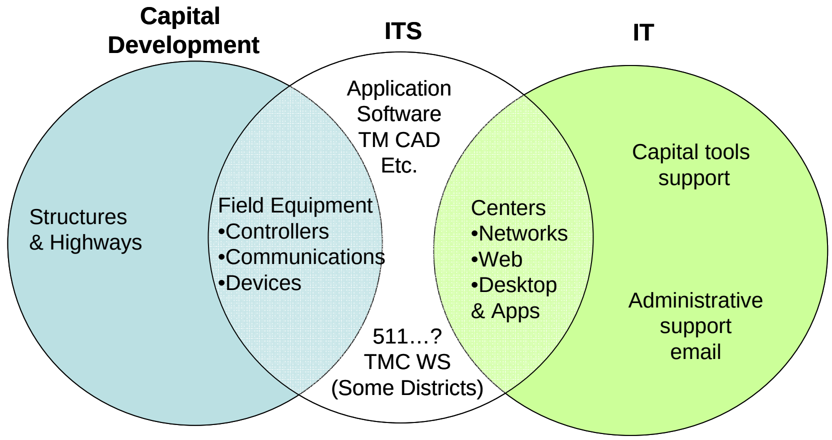

Figure 4: ITS, Capital, and IT projects

A traditional capital development project that includes an ITS element such as a traffic signal or a ramp meter, is an ITS project. This is represented by the overlap between the Capital Development and ITS projects in the figure. The traditional capital development process is generally used for these types of projects, but the ITS elements within the project are also subject to the systems engineering requirements in 23 CFR 940.

Similarly, there is significant overlap between IT projects and ITS projects. The state defines an IT project in the State Administrative Manual Section 4819.2 as:

> A project that encompasses computerized and auxiliary automated information handling, including systems design and analysis, conversion of data, computer programming, information storage and retrieval, data transmission, requisite system controls, simulation, and related interactions between people and machines.

This very broad definition for IT projects could be interpreted to include any information processing system. In practice, ITS projects that include center application software, computers, and networks are classified as IT and would be subject to IT (DOF) processes and requirements.

Systems Engineering and the ITS Architecture

A systems engineering approach for ITS projects requires up-front planning and system definition so that project requirements are identified and documented, before technology choices are made and the system is implemented. A regional ITS architecture, required by 23 CFR 940, is a framework that supports this up-front planning since it allows ITS projects to be viewed in the broader context of the regional transportation system. Among other benefits, US DOT promotes development of a regional ITS architecture because it helps integrate operational considerations into the strategic planning process. The best opportunity for using the regional ITS architecture is early in the systems engineering process, when the project is initiated and preliminary engineering is performed. The architecture is most valuable as a scoping tool that allows a project to be broadly defined and shown in a regional context. In later steps in the systems engineering process, when the project scope is more firmly established and the project is defined in increasing detail, there is less opportunity to use the high-level definitions included in the

regional ITS architecture.

What is Process?
A process is a set of practices performed to achieve a given purpose. It may include tools, methods, materials, and/or people. While process is often described as a leg of the process-people-technology triad, it may also be considered the glue that unifies the technology with people.

"The quality of a product is largely determined by the quality of the process that is used to develop and maintain it." This quote is based on Total Quality Management (TQM) principles as taught by Shewhart, Juran, Deming and Humphrey. (CMMI V1.1 and Appraisal Tutorial) SEI.

What is Capability?
In this context, "capability" is the ability and capacity of an organization to achieve a desired result. Systems engineering requires a number of capabilities. For example, the capability to develop requirements, manage requirements, etc. Different organizations have different levels of capability, depending on the processes and practices that they have in place, and the ability of the organization to use and apply those processes and practices.

1.3 Systems Engineering Process Requirements

There are a number of process-related requirements that apply to ITS projects that are levied by FHWA and other federal and state agencies. Since ITS projects are so varied, ranging from field equipment procurement through major system integration and software development projects, different requirements will apply to different projects. As shown in Figure 5, ITS projects may be subject to requirements associated with the Capital Development process as well as the IT project development process.

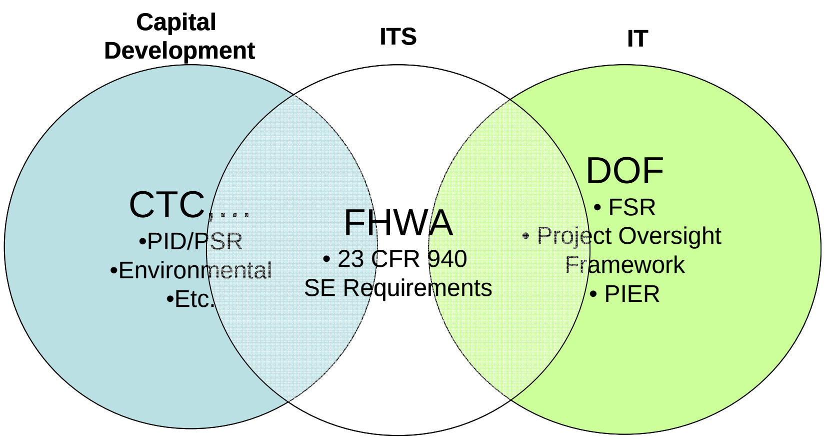

Figure 5: ITS, IT, and Capital Development Process Requirements

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1.3.1 Federal Highway Administration

The FHWA systems engineering requirements for ITS projects are included in 23 CFR 940 (commonly referred to as "the final rule"). Part 940.11 of this rule defines seven specific requirements that must be included at a minimum in the systems engineering analysis. Part 940.13 of the rule requires compliance with the systems engineering requirements to be demonstrated prior to authorization of highway trust funds. This compliance is monitored by the FHWA division offices under existing federal oversight procedures.

Currently, the FHWA oversight of Caltrans ITS projects is handled informally on a project-by-project basis. The Department would like to be self certified in ITS project development with respect to FHWA oversight. FHWA would like to work with Caltrans to document a procedure for FHWA oversight of Caltrans ITS projects based in part on the outcome of this Systems Engineering evaluation project.

Caltrans Local Assistance Procedures

It is likely that the oversight procedures for Caltrans ITS projects would be similar to the procedures that FHWA uses to provide oversight for ITS projects that are developed by local agencies in California. In 2004, the Caltrans Local Assistance Procedures were revised to address the requirements in 23 CFR 940 for local agency projects. The revised Local Assistance Procedures include three significant new elements that address the systems engineering requirements:

1.) Systems Engineering Review Form (SERF) – Completed at beginning of a project as part of the Field Review Form, this form summarizes activities needed to meet the Architecture Rule requirements that all ITS projects must undertake a Systems Engineering Analysis. The form includes seven questions that exactly correspond to the seven requirements in 23 CFR 940.11

2.) Systems Engineering Management Plan (SEMP) – Completed in early phases of system development, to serve as part of the Project Management Plan, the SEMP identifies the "best professional practices" to manage and undertake the technical tasks.

3.) Systems Engineering Process – As defined in the SEMP, this process establishes the design, implementation, and testing steps necessary to accomplish the system implementation in a manner that is scaled to the size and risk of the project.

SYSTEMS ENGINEERING REVIEW FORM

This form needs to be filled out for all ITS projects. For all major ITS projects, this completed form needs to be submitted to FHWA for review and approval prior to PE authorization (Phase 1 PE authorization).

For all major ITS projects, a Systems Engineering Management Plan (SEMP), which includes the seven items below, must be submitted to FHWA for review and approval, prior to PE authorization for final or detailed design (Phase 2 PE authorization). The 2-phased PE authorization only applies to major ITS projects.

For guidance in filling out the seven items below, see last part of this exhibit.

1. Identification of portions of the Regional ITS Architecture being implemented:

___

2. Identification of participating agencies roles and responsibilities:

___

3. Requirements definitions:

___

4. Analysis of alternative system configurations and technology options to meet requirements:

___

5. Procurement options:

___

6. Identification of applicable ITS standards and testing procedures:

___

7. Procedures and resources necessary for operations and management of the system:

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Figure 6: SERF Form Supporting 23 CFR 940.11 in California

Currently, local agencies are required to complete the SERF for all ITS projects. The SERF only requires approval from Caltrans Local Assistance and FHWA for higher risk ITS projects that include new system functionality (e.g., ITS projects that include substantial new software development). The SEMP must also be prepared and submitted to Caltrans Local Assistance and FHWA for these higher risk projects. The project sponsor (the local agency) determines whether the project is a higher risk project that requires the additional oversight based on guidelines in the Local Assistance Procedures and supporting guidance.

If a similar process were to be used for Caltrans ITS projects, then the "higher risk" projects that include additional FHWA oversight would often be the same projects that also are subject to DOF oversight requirements. One of the key objectives of this evaluation is to identify ways to minimize the impact of this "double jeopardy" oversight of the systems engineering processes by two different agencies.

1.3.2 Department Of Finance

The initial scope of work for this project focused on systems engineering requirements levied by FHWA, but the Team learned early in the data collection effort that the Department of Finance's oversight requirements were actually more of a concern to many ITS project managers. To better understand the DOF's requirements and their applicability to ITS projects, the Department of Finance was interviewed as part of the data collection effort for this project. The notes from this interview are included in Appendix C. The key DOF requirements as they apply to ITS projects are briefly described here.

Feasibility Study Report (FSR)

The State Acquisition Manual (SAM) requires a feasibility study to be performed for every IT project. For projects that exceed Caltrans departmental budget authority ($500k), a FSR must be prepared and submitted to DOF for approval. An FSR is required whether the project is funded with local, state, or federal funds since it is spending authority, not budgets, which are approved.

The FSR must contain the following information:

1. A description of the business problem or opportunity the project is intended to address.
2. The project objectives, i.e., the significant results that must be achieved for an alternative to be an effective response to the problem or opportunity being addressed.
3. A thorough description of the selected alternative, including the hardware, software and personnel that will be used.
4. A discussion and economic analysis of each of the alternatives considered in the feasibility study that meets the established objectives and functional requirements, and the reasons for rejecting the alternatives that were not selected.
5. A complete description of the information technology capabilities and the conditions

The FSR Process: Perceptions and Reality

Perception: The FSR must be done at the beginning of project development.
Reality: Caltrans has considerable latitude in establishing when the FSR is prepared in the project development process. For example, an FSR could be generated after the analysis and design steps in the systems engineering process. The only limitations are that Caltrans would have to find a way to fund the pre-FSR work and the FSR must be submitted and approved before operational hardware/software is developed/procured.

Perception: DOF will only approve projects that will yield hard Person Year (PY) savings.
Reality: Hard PY savings are not required for project approval; broader economic/social benefits are also acceptable justification for a project. DOF has approved projects based on projected service to the public.

Perception: DOF requires the Project Manager to be from the IT Division.
Reality: DOF focuses on qualifications and expects the project managers to have relevant experience. For example, the project manager for a software-intensive project should have experience in managing software acquisition. The experienced individual can come from any division within Caltrans, per DOF. The Caltrans IT Division is actually levying this requirement.

that must exist in order to satisfy each defined objective.
6. An economic analysis of the life cycle costs and benefits of the project and the costs and benefits of the current method of operation during the life cycle of the project.
7. The source of funding for the project.
8. A detailed project schedule showing key milestones during the project's life.

While DOF provides detailed guidelines for the FSR (SIMM Section 20), there is some latitude in the format and structure of the documentation that is submitted, as long as the required content is provided. In general, the FSR content requirements reflect key outputs of the systems engineering process. As one attendee noted during the DOF interview, "The FSR is really the result of systems engineering analysis with a signature page at the front and economic justification forms at the end".

One of the key issues with the FSR process from Caltrans' perspective is the lengthy delays in the FSR approval process. There have been numerous initiatives that have attempted to facilitate the FSR process, but the state budget process really drives the FSR process and the associated delays. FSRs are reviewed and approved and projects are funded on the following timeline:

- FSR is written
- FSR is processed through the Caltrans signature cycle up through the deputy director and CIO (may require months and numerous revisions to get required signatures).
- FSRs are submitted to DOF once a year in July.
- The associated budget changes are identified in early fall. Project "approval" occurs in the fall, but it is kept a secret until the Governor's budget is issued.
- The Governor's budget is issued in early January.
- Following negotiations, the budget is approved and signed some time in July.

Thus, a one year delay is built into the timeline between the time FSRs are submitted to DOF in July and the earliest that spending authority can be received for the project the following July.

Other key issues with the FSR process that were identified during the Caltrans interviews included:

- The DOF analyst's primary expertise is with traditional IT projects. ITS transportation projects are not as familiar to DOF staff.
- The FSR is prepared very early in the project development cycle, which makes it extremely difficult to generate accurate cost estimates and provide the level of detail required in the FSR.

Much of the FSR content is a natural by-product of the systems engineering process as shown in Table 1. If the FSRs were developed later in the project development process, the FSR content could be derived from the project systems engineering analysis.

Table 1: FSR Content and the Systems Engineering Process

FSR Content Requirement	Supporting Systems Engineering Process
1. A description of the business problem or opportunity the project is intended to address.	Concept Exploration
2. The project objectives, i.e., the significant results that must be achieved for an alternative to be an effective response to the problem or opportunity being addressed.	Concept of Operations
3. A thorough description of the selected alternative, including the hardware, software and personnel that will be used.	High Level Design
4. A discussion and economic analysis of each of the alternatives considered in the feasibility study that meets the established objectives and functional requirements, and the reasons for	Concept Exploration

FSR Content Requirement	Supporting Systems Engineering Process
rejecting the alternatives that were not selected.	
5. A complete description of the information technology capabilities and the conditions that must exist in order to satisfy each defined objective.	Concept of Operations, System Requirements
6. An economic analysis of the life cycle costs and benefits of the project and the costs and benefits of the current method of operation during the life cycle of the project.	Cost/Benefits Analysis
7. The source of funding for the project.	Project Plan
8. A detailed project schedule showing key milestones during the project's life.	Project Plan/Systems Engineering Management Plan

Project Oversight Framework

DOF maintains the IT Project Oversight Framework which defines the minimum requirements for IT project management, risk management, systems engineering, project oversight, and project reporting activities. Similar to FHWA's distinction between ITS projects of different risk levels for local assistance, DOF defines a graduated project criticality scale based on project size and type and the project manager's and team's experience, which is used to establish the process activities and the level of oversight that is required for each project. Medium or high criticality projects, as defined by this scale, require project oversight reporting to DOF on a quarterly or monthly basis respectively. Although the process requirements identified in the Oversight Framework focus on project management, there are a number of systems engineering requirements that are also levied, as shown in Table 2.

Table 2: DOF Required Systems Engineering Practices

Low Criticality Projects	Medium Criticality	High Criticality
	Ongoing user involvement	Ongoing user involvement
Formal user approval/sign-off on written specifications	Formal user approval/sign-off on written specifications	Formal user approval/sign-off on written specifications
	Adherence to a formal system development life-cycle (SDLC) methodology	Adherence to a formal system development life-cycle (SDLC) methodology
	Tracking requirements traceability through life-cycle phases	Use of requirements management software and tracking of requirements traceability through life-cycle phases
	Adherence to software engineering standards	Adherence to software engineering standards
	Software defect tracking beginning with unit testing	Product defect tracking beginning with requirements specifications
	Performance of formal code reviews	Performance of formal code reviews
	Formal quality assurance through all life-cycle phases	Formal quality assurance through all life-cycle phases
Formal testing and user sign-off of test results and completed system	Formal testing and user sign-off of test results and completed system	Formal testing and user sign-off of test results and completed system
		Adherence to an enterprise architecture plan
		Deliverable inspections, beginning with requirements specifications
		Formal IV&V

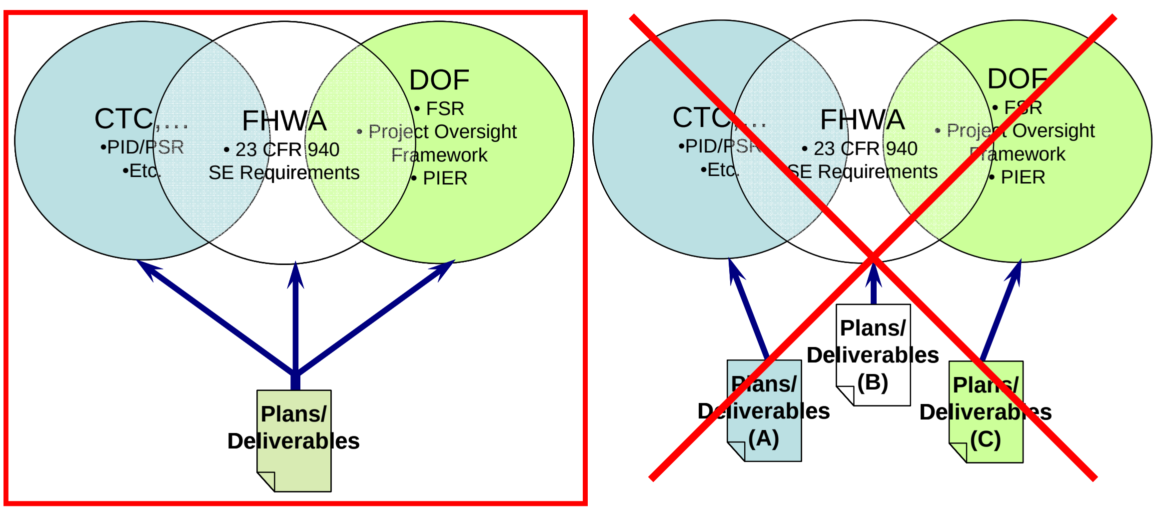
Post Implementation Evaluation Report (PIER)
A Post Implementation Evaluation Report (PIER) must be submitted to DOF within 18 months of project completion for all non-delegated projects. There is a one to one correspondence between the FSR and PIER – the FSR starts the project and PIER closes the project. The PIER identifies what worked and what didn't, whether the objectives were met, etc. The PIER transmittal and approval formally closes the project.

1.3.3 Caltrans Capital Development Requirements

Capital Development projects are also subject to process and documentation requirements. For example, the California Transportation Commission requires a complete Project Study Report for any project that is included in the RTIP or ITIP. Similar to the DOF FSR requirement, the PSR is intended to define and justify the project scope, cost, and schedule. ITS Field Equipment projects and any other project that is programmed through the RTIP or ITIP will also be subject to these requirements. A mature process exists for capital project development. The Department's goal is leverage existing processes and define a common set of processes for ITS development. These common processes will be integrated into the Department's existing processes, enabling ITS projects to be mainstreamed within the Department's overall project development process.

1.3.4 Objective – Unified Requirements

From the Department's perspective, a key objective is to have a single well-defined systems engineering process and single stream of project deliverables that satisfy the state and federal requirements related to systems engineering for ITS projects. Caltrans should work with FHWA and DOF (and other agencies as necessary) to achieve a common understanding of how to develop a good systems engineering process that addresses risk while minimizing redundant work/duplicative outputs to satisfy similar, but not identical, requirements from multiple agencies.



1.4 Task 2 Overview – Data Collection and Preliminary Assessment

This final report builds on the data collection and preliminary assessment activities performed in Task 2 of this project. The complete Task 2 documentation is available under separate cover (see the "Task 2 Draft Report: Systems Engineering Evaluation for ITS". A summary of the Task 2 findings is included here.

In Task 2, the Consultant Team (ASE Consulting LLC and R.C. Ice and Associates) collected data on the best practices in systems engineering that are currently being performed within the Department. Data was collected for Capital Development, Information Technology, and Intelligent Transportation Systems project processes and capabilities. Industry best practices were also reviewed to provide context and background for the Caltrans data collection effort. The data collection effort consisted of documentation review that was supplemented by a series of interviews. The approach that was used is shown in Figure 7

Figure 7: Task 2 Approach

1.4.1 Caltrans Documents

The Consultant team obtained and reviewed over 100 documents as part of the Task 2 effort. In addition to the Project Development Procedures Manual (the "Gold Book"), many key documents were collected from each division that provided real insight into the Caltrans Project Development Process. A significant number of the documents are available from the Caltrans website and many additional documents were identified during the interviews and passed along by interview participants. The task 2 interim report includes a complete list of the documents that were collected, sorted by the Division that provided the document.

1.4.2 Caltrans Interviews

The Caltrans coordinator did an excellent job of making a range of domain experts from the department available for interviews. Interviews were conducted with thirteen (13) Divisions, three (3) Districts, key offices, individual experts, and five (5) follow-up interviews. The interviews were critical to the data collection effort since they allowed the consultant team to move beyond the documents and learn first-hand how the project development process really works within Caltrans. The interviews provided valuable context for the documentation review, affirming the documented process and providing information on the roles and responsibilities of each of the divisions at headquarters and in each of the districts. A complete list of interview participants and a comprehensive set of interview notes is included in the task 2 interim report.

Table 3: Interviews

Division (or Group) Interviewed	Interview Date
Information Technology	April 5, 2005 AM
	May 31, 2005 PM*
Design	April 19, 2005 AM

Division (or Group) Interviewed	**Interview Date**
(Value Analysis)	May 27, 2005 AM
Local Assistance	April 19, 2005 PM
Research and Innovation	April 20, 2005 AM
Project Management	April 20, 2005 PM
Transportation Information Systems	April 21, 2005 AM
Construction	April 21, 2005 PM
	June 1, 2005 AM*
Traffic Operations	April 27, 2005 AM
	June 1, 2005 PM*
Planning	April 27, 2005 PM
	May 31, 2005 AM*
Environmental Analysis	April 28, 2005 AM
(IT Project Management)	May 18, 2005 AM
Engineering Services	May 19, 2005 AM
Maintenance	May 19, 2005 PM
	November 3, 2005*
(District 8)	November 1, 2005
(District 7)	November 2, 2005
(District 3)	November 3, 2005
Department of Finance	**March 3, 2006**

* Follow-up Interview

1.4.3 Industry Best Practices and Standards

The data collection effort also included a review of current industry best practices and standards for systems engineering. The Consultant team reviewed a number of systems engineering standards (e.g., IEEE 1220, EIA 632, and ISO 15288). The team also reviewed capability models including the Software Engineering Institute's (SEI) capability maturity models – CMM (Software), SA-CMM, (Software Acquisition), EIA 731 SECM (Systems Engineering), United Kingdom's Smart Acquisition IPT Relationship Maturity Model (IPT Relationships) and SEI's Capability Maturity Model Integration (CMMI) for Systems & Software Engineering, and Integrated Product Development. Complementing these industry standards and models, several related works that are specific to ITS were also reviewed, including the Systems Engineering Guidebook For ITS (co-sponsored by Caltrans and FHWA).

1.4.4 CMMI Model Selection

A key purpose for the review of industry best practices was to identify an industry-standard reference model that is best suited for the evaluation of the Department's systems engineering capabilities in Task 3. This reference model will provide a benchmark or "measuring stick" that the consultant team will use to objectively measure the Caltrans Systems Engineering process in Task 3.

Since CMMI incorporates practices from CMM, SA-CMM and SECM, CMMI provides the broadest and best integrated reference model that fully covers the technical capabilities that are required for ITS project development. Since it is the best candidate, a more detailed review of CMMI was conducted, including the associated appraisal requirements and methods in preparation for Task 3.

Appendix B provides background information on CMMI, including a detailed list of best practices. The CMMI categories and process areas that will be used in the evaluation are shown in Figure 8.

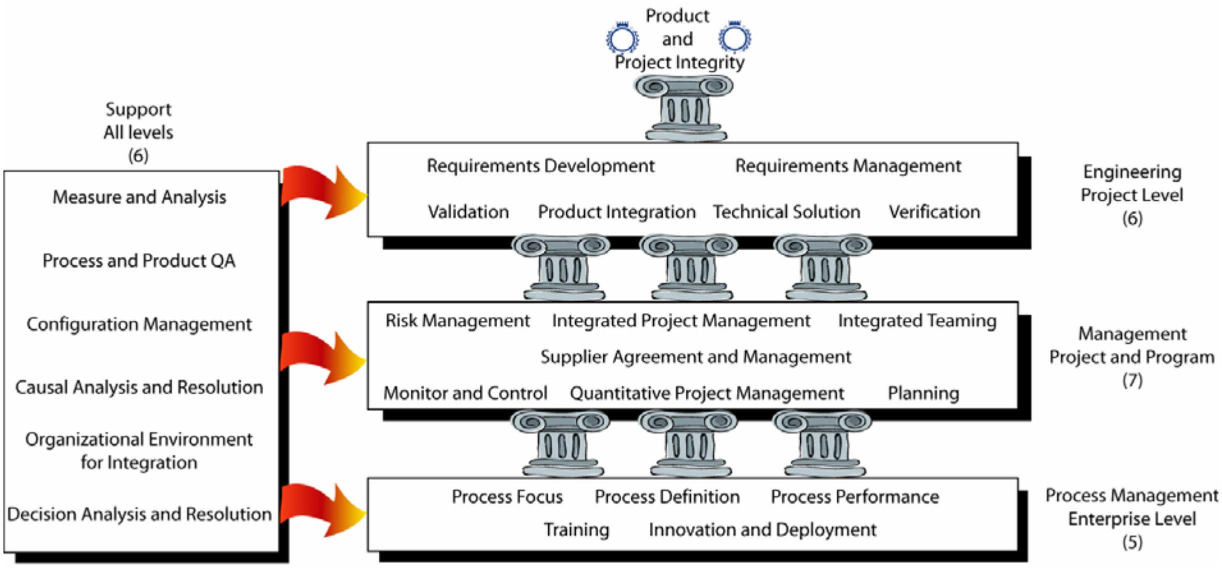


Figure 8: CMMI Categories and Process Areas

2 Evaluation

This is the first independent evaluation of system engineering processes for ITS Projects that has been performed for the Department. This initial evaluation will provide an overall assessment in the four CMMI categories of Project Management, Support, Engineering, and Process Management and their associated process areas as they relate to systems engineering. The purpose of this evaluation is to support process improvement, which means the focus is on identification of strengths and weaknesses and opportunities for improvement in each area.

The evaluation process that was used is shown in Figure 9 and elaborated in the following paragraphs.

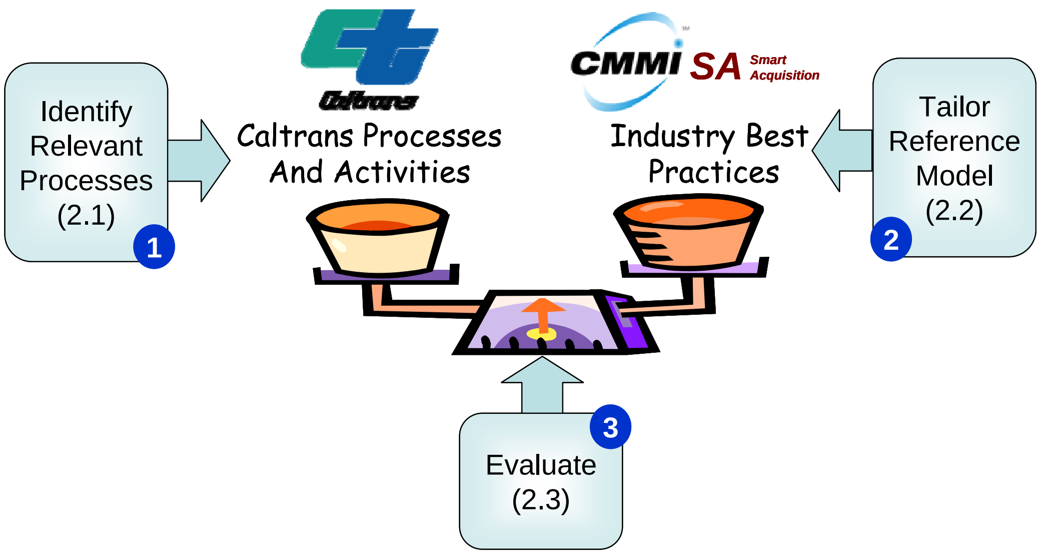


Figure 9: Systems Engineering Evaluation Approach

2.1 Caltrans Processes and Activities

The data collected through the document reviews and interviews in Task 2 was the basis for the evaluation. Table 4 lists the key documented systems engineering processes, related handbooks, and project artifacts that were identified. These systems engineering processes and activities can be applied to the implementation of systems engineering for ITS projects within the Department.

Table 4: Key Caltrans Processes and Activities

Direct Process Development Activities
DOT – Capital Development process – published & established process
DOF- Information Technology Project Oversight Framework – published
DOF – Feasibility Study Report, Independent Oversight, Project evaluation
DOT (Research & Innovation) - Systems Engineering Guidebook for ITS – Version 1.0 published, Version 2.0 in development
DOT (Information Technology) - Systems Development Life cycle processes – in-development
Other Key Relevant DOT Processes and Activities
Division of Traffic Operations – Pre-CATMS projects
Division of Traffic Systems Information – TIMI, Data modeling
Division of Transportation Planning – Capital planning activities and training
Division of Project Management – Project Management, Risk Management, and

Table 4: Key Caltrans Processes and Activities

	Communications Handbooks
	Division of Maintenance Electrical guidelines
	Division of Design – Value Analysis
	Division of Local Assistance – Program guidelines for ITS
	District 7 ITS development practices – Integrated team & corridor approach

2.2 Tailoring CMMI for the Caltrans Evaluation

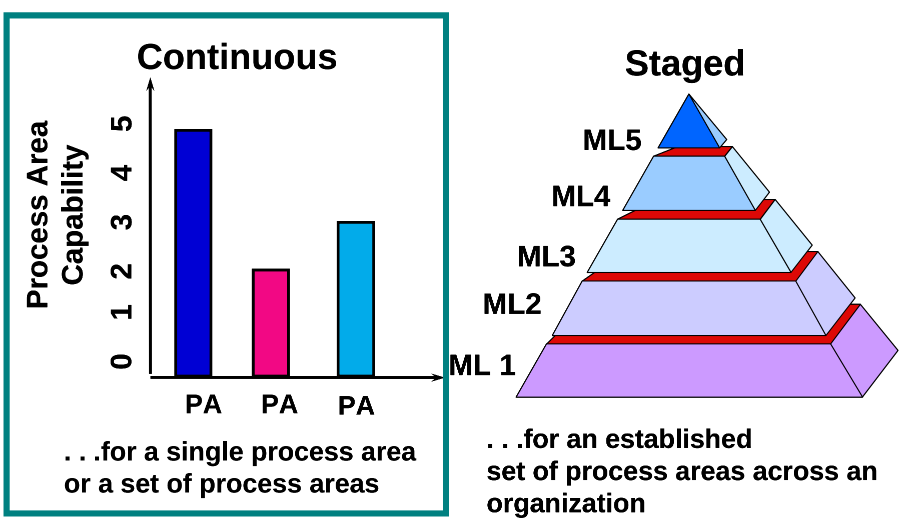
CMMI assessments are normally performed at a project level. This means that the assessment team would interview the participants on a specific project (or projects) to assess what processes and practices were performed. For this assessment of the Department, the team did not have a specific project to evaluate. Instead, the team looked at the organizational capabilities and processes to assess the overall systems engineering capabilities of the Department. Rather than looking at the 189 specific practices that a particular project addressed, the team evaluated the SE capabilities at a higher level, rolling up the specific practices to process areas and categories that can more easily be assessed at the organizational level.

For example, “Plan for Data Management” is a defined practice in the Process Area “Project Planning”, within the “Project Management” category. Some projects may need a Data Management plan and other projects may not. In this evaluation, the focus was on the organizational level, making sure that Project Planning policies are established for such plans. The specific practices to be performed are identified at the project level.

2.2.1 Which CMMI representation to use?

As described in the background on CMMI in Appendix B, the CMMI includes two representations: 1) staged and 2) continuous. In Task 2, we determined that the Department’s evaluation results should be presented in the continuous representation for the following reasons:

- It provides visibility into capabilities in individual process areas
- It provides freedom to select the order of improvement to best meet Caltrans objectives



For example, the initial goal may be to meet the FHWA final rule requirements for systems engineering. In that case, a focus on CMMI process areas for Engineering and Project Management that are related to Rule 940 would be addressed as a priority.

2.2.2 Process Area Focus for this Evaluation

Using the continuous representation allows the team to focus on the process areas within CMMI that are most pertinent to Caltrans' needs and directly related to federal and state process requirements. The following table identifies the process areas that support process requirements levied by DOF and FHWA and process areas that are recommended for Caltrans. The recommended process areas are those that are included in Level 3 in the Staged Representation of CMMI and the process areas that are identified for acquisition organizations in the CMMI Acquisition Module published in May 2005. The right-most column in the table identifies all process areas that are either required or recommended; these process areas are the focus of the evaluation of the department.

Table 5: Required and Recommended Process Areas

	Process Areas	Required		Recommended		Focus Areas
		DOF	FHWA	Level 3	Acquisition	
Project Management	Project Planning	Required	Required			Required
	Project Monitoring and Control	Required				Required
	Supplier Agreement Management	Required	Required		(1) (2)	Required
	Integrated Project Management (IPPD)					
	Integrated Supplier Management (SS)				(1)	
	Integrated Teaming (IPPD)					
	Risk Management	Required				Required
	Quantitative Project Management					
Support	Configuration Management	Required				Required
	Process and Product Quality Assurance	Required				Required
	Measurement and Analysis					
	Causal Analysis and Resolution					
	Decision Analysis and Resolution	Required				Required
	Organizational Environment for Integration				(2)	
Engineering	Requirements Management	Required				Required
	Requirements Development	Required	Required			Required
	Technical Solution	Required	Required			Required
	Product Integration	Required	Required			Required
	Verification	Required	Required			Required
	Validation	Required				Required
Process Manageme	Organizational Process Focus	Required				Required
	Organizational Process Definition	Required				Required
	Organizational Training					
	Organizational Process Performance					
	Organizational Innovation and Deployment					

(1) CMMI-AM defines a "Solicitation and Contract Monitoring" process area that relates to these two process areas.
(2) CMMI-AM defines a "Transition to Operations and Support" process area that expands on/loosely relates to these process areas.

2.2.3 CMMI Capability Levels

Although not as rigorous or detailed as a benchmark assessment, this evaluation does perform a high-level assessment of the Department's "capability level" in each category of process areas. As shown in Figure 10, there are six capability levels defined in CMMI, ranging from Incomplete (0) to Optimizing (5). Each level is a layer in the foundation for continuous process improvement. The capability levels are cumulative – a higher capability level includes the attributes of the lower levels. These capability levels provide a defined way to score an organization's processes. They also provide a roadmap for process improvement.

5 Optimizing	Defect prevention, proactive improvement, innovative technology insertion
4 Quantitative	Measure process performance, stabilize process, control charts, deal with causes of special variations
3 Defined	Project's process is tailored from organization's standard processes
2 Managed	Policy established, Follow documented plans/processes, Assign responsibilities, Train people, Configuration Management Monitor and control process, Identify and involve stakeholders, Review with management
1 Performed	Perform the work
0 Incomplete	Not performed, incomplete

Figure 10: CMMI Capability Levels

2.2.4 Evaluation of Organizational Relationships

One of the key findings from the interviews was how critical organizational relationships are to the ITS project development process. Challenges posed by working relationships between Caltrans and other departments, between divisions within Caltrans, and between the districts and headquarters were identified. An ITS project may require involvement of not only the Districts and Divisions within the Transportation Department but the Department of General Services and the Department of Finance. These relationships are critical to the successful implementation of ITS projects.

As a result, this evaluation addresses not only organizational capabilities, but relationships between organizations that cross Divisional, Departmental and District boundaries. To support this aspect of the evaluation, another maturity model was identified - the IPT Relationship Maturity Model that specifically addresses Integrated Product Team relationships (see Appendix C). This model is used to characterize the perceived relationships within the Department with regard to ITS developments.

2.3 Systems Engineering Evaluation

This section evaluates the Caltrans processes and activities identified in section 2.1, comparing them against the tailored CMMI model described in section 2.2. The evaluation results are documented here for all four CMMI categories - Project Management, Support, Engineering, and Process Management. An overall evaluation of each process category is performed, followed by a selective assessment of the key process areas in that category as they relate to systems engineering.

2.3.1 Project Management

The CMMI Project Management category covers activities related to planning, monitoring, and controlling the project. There are eight Project Management process areas:

- Project Planning - Establish and maintain plans that define project activities.
- Project Monitoring and Control - Provide understanding into the project's progress so that appropriate corrective actions can be taken when the project's performance deviates significantly from the plan.
- Supplier Agreement Management - Manage the acquisition of products from suppliers for which there exists a formal agreement.
- Integrated Project Management - Establish and manage the project and the involvement of the relevant stakeholders according to an integrated and defined process that is tailored from the organization's set of standard processes.
- Integrated Supplier Management - Proactively identify sources of products that may be used to satisfy the project's requirements and to manage selected suppliers while maintaining a cooperative project-supplier relationship.
- Risk Management - Identify potential problems before they occur, so that risk handling activities may be planned and invoked as needed across the life of the product or project to mitigate adverse impacts on achieving objectives.
- Quantitative Project Management - Quantitatively manage the project's defined process to achieve the project's established quality and process-performance objectives.

The Project Management process areas are vital to the Department for all projects, including ITS projects. The importance of these areas is recognized within the Department, which is reflected in mature, well-documented project management processes and skilled and experienced project management personnel. The key challenge in this area is applying these proven processes to ITS projects, harnessing the strengths and skills of the PM, IT, and other Caltrans divisions.

Project Management – Overall Assessment

STRENGTHS AND WEAKNESSES	+ **Capital development project management is well documented, established and practiced** within the Department. Based on PMBOK best practices. Many of the CMMI specific project management practices have flowed over to the management of ITS projects, especially in the implementation of ITS field elements. Many of these project management practices are shared with IT Application developments. + **Capital development project communications, stakeholder involvement, integrated product team, risk management practices all mature** and well suited to ITS Projects –minor adaptation to accommodate ITS technology focus is required. - **ITS projects must deal with two different processes within the department**: 1) the traditional capital development processes for the ITS field elements and 2) the legislative requirements for IT Application development projects. As a result, ITS project management practices must accommodate both processes as well as industry best practices for technology projects. - **Capital development project management processes do not address some technology project-specific issues** including development of technical plans e.g. (integration, verification, validation, security, development) - **Setting realistic expectations for the stakeholders**
INITIAL ASSESSMENT & RATIONAL	**ITS Field Equipment Projects** Level 2+ (Managed) - Most of the CMMI goals are met. The project management process is defined and managed by PM and Design divisions. **ITS Application Development** Level 0 (Incomplete) - Processes that support ITS Application Development are currently incomplete. Lack of consensus between divisions. Individual project successes rely on talented, dedicated personnel. The only documented process provided was the DOF IT Project Oversight Framework, which has not been used for ITS projects to date. Documented processes are starting to emerge through the use of the Systems Engineering Guidebook for ITS and the developing processes from the Division of Information Technology.
LEVERAGE *Existing Processes and Practices*	• DOF - Information Technology Project Oversight Framework • DOT - Systems Engineering Guidebook for ITS • DOT - IT Systems Development Life cycle processes currently under development. • Division of Project Management's – Project Management, Risk Management and Communications Handbooks • Division of Local Assistance – Program guidelines for ITS • District 7's integrated project management approach could be used as model for ITS project developments • Industry – PMI Project Management Body of Knowledge

Project Management – Process Area Assessment

PROCESS AREAS *Required and recommended areas*	- **Project Planning** — Required + **Project Monitoring and Control** — Required - **Supplier Agreement Management** — Required + Integrated Project Management(IPPD) — Recommended + Integrated Supplier Management (SS) — Recommended + Integrated Teaming (IPPD) — Recommended + **Risk Management** — Required - Quantitative Project Management — Future + = *Performed* - = *Incomplete*
PROJECT PLANNING *Recommended process area improvements*	• *Review plans that affect the project* - As required by FHWA, Planning needs to include framework (annotated outline or template for the plan) for each technical plan envisioned for the project. These plans would be identified (as part of the tailoring process) for the project based on project needs and risks. For example, replacing existing legacy system will most likely require a transition plan to move from the existing to the new system. This upfront planning helps to identify risks as early as possible. • *Defining project life cycle* – Define a model that is synchronized and coordinated with the legislative requirements for IT projects. For example, Feasibility Study Reports could be submitted just prior to the Detailed design phase. At this point the cost estimates, benefits, requirements would have been well defined and if summarized this would provide the needed documentation for the FSR deliverable. Then start the procurement documentation, Request for qualifications, evaluation of alternatives
SUPPLIER AGREEMENT MANAGEMENT *Recommended process area improvements*	• *Determine Acquisition type*- As required by both DOF and FHWA, Alternative acquisition methods are evaluated and the preferred method identified. • *Select Suppliers* - Also an assessment of the quality of COTS vender should be determined. For example, does the vendor have Configuration Management process such that the agency receives product updates, notice of revisions and/or notice of design changes on products the Agency has purchased. This may require a maintenance agreement to receive this support.

2.3.2 Support

The CMMI Support category covers the essential practices that support ITS project development. They include crosscutting processes such as configuration management, quality assurance, and decision analysis that support the other systems engineering processes. There are six Support Process Areas:

- Configuration Management - Establish and maintain the integrity of work products using configuration identification, configuration control, configuration status accounting, and configuration audits.
- Process and Product Quality Assurance - Provide staff and management with objective insight into processes and associated work products.
- Measurement and Analysis - Develop and sustain a measurement capability that is used to support management information needs.
- Causal Analysis and Resolution - Identify causes of defects and other problems and take action to prevent them from occurring in the future.
- Decision Analysis and Resolution - Analyze possible decisions using a formal evaluation process that evaluates identified alternatives against established criteria.
- Organizational Environment for Integration - Provide an Integrated Product and Process Development (IPPD) infrastructure and manage people for integration.

These support process areas are important to the Department, whether the Department is acting as an acquisition organization or as a system developer/integrator for a particular ITS project. Like in the broader transportation industry and other industries, these process areas seem to get less attention than many other process areas. Informal ad hoc techniques can be used on smaller projects, but large, complex projects require documented processes and more formal methods.

Support – Overall Assessment

STRENGTHS AND WEAKNESSES	+ **The "Gold book" includes documented processes** for the Configuration Management and Organizational Environment for Integration Process Areas. + **The Project Management Handbook** specifies a Quality Management Plan. The Project Communications Handbook defines tools and techniques to integrate the project team and associated stakeholders. + **The Departments Value Analysis process** touches on areas of Measurement, Decision Analysis and Resolution for capital projects. + **Configuration Management tools are used for some ITS projects** such as the Computer Associates Harvest tool used of ATMS software. At the system level CM for requirements, documentation will be done by Serna RTM. + **District 7 provides management support for integrated project teams that include ITS practioners** with positive results. This could be an example for district implementations. - **Complete processes that address all aspects of CM have not been implemented.** The team found no objective evidence of CM Planning, Confuguration Management Boards, change control processes, status accounting, and audits. - **Few ITS projects have shown evidence of performing Measurement & Analysis or Decision Analysis & Resolution.** Showcase performed an analysis on the value of motorist information. - **For ITS projects, measurement and decision analyses are done informally using engineering judgment and a consensus process** rather than using tools and methods or models that yield quantitative results.
INITIAL ASSESSMENT & RATIONAL	**<u>ITS Field Equipment Projects and ITS Application Developments</u>** Level 0 (Incomplete) - The majority of the support process areas have not been practiced in any significant way and when performed, they are usually done using engineering judgment. Configuration Management for ITS is also at its beginning phases. Support processes are performed on selected projects (e.g., CATMS and District 7 ITS projects).
LEVERAGE *Existing Processes and Practices*	• DOT - Gold Book section on Change management • DOT - Systems Engineering Guidebook for ITS has guidance on Configuration Management, Trade study approach (Decision support), and Process assessment • DOT - District 7 integrated project management practices (undocumented) • Division of Project Management's – Project Management and Communications Handbooks • Industry - EIA 649 Standard - National Consensus on Configuration Management & Mil Handbook 61 on Configuration Management

Support – Process Area Assessment

PROCESS AREAS *Required and recommended areas*	- **Configuration Management** — Required - **Process and Product Quality Assurance** — Required - Measurement & Analysis — Recommended - Organizational Environment for Integration — Recommended - **Decision Analysis & Resolution** — Required - Causal Analysis & Resolution — Future + = *Performed* - = *Incomplete*
Configuration Management *Recommended improvements*	• *Define practice for establishing baselines and getting stakeholder buy-in.* This would provide a significant step in managing the integrity of the system, and producing quality documentation. • *Establish a standing change control board at the Department level with satellite representatives at the District level.* This board would implement processes (Configuration Identification, audits, change tracking, change management, and record keeping) that are used to manage the baselines and maintain the integrity of the system and project products.
Process and Product Quality Improvement *Recommended improvements*	• *Provide independent review of project processes.* Independent review would support DOF project oversight requirements and ensure processes are meeting the intent and performing as expected. • *Keep records on process performance*
Measurement & Analysis *Recommended improvements*	• *Define measurement and analysis standards for the Department, focusing initially on project measures.* Specify standard project measures based on management objectives. Document data collection and storage procedures. Define standard data visualization and analysis techniques.
Organizational Environment for Integration *Recommended improvements*	• *Start by establishing a shared vision that is consistent between headquarters and district..* Identify the needed skills, establish leadership for the team, identify incentives for integration, establish an organizational structure. • *Review and document the District 7 processes for the integration of project teams and the integrated corridor approach to projects.* Districts with the most ITS experience have developed processes that may be broadly applied.
Decision Analysis and Resolution *Recommended improvements*	• *Establish guidelines for making decisions.* Identify when a structured decision analysis is required. Address evaluation criteria, identification of alternatives, evaluation methods, and documenting rationale for selection. Consider modeling tools and methods as well as decision support tools such as decision trees, trade study methods, pair-wise comparisons, and Quality Function Deployment (QFD).

2.3.3 Engineering

The CMMI engineering category includes the core systems engineering process areas that develop and manage requirements, define technical solutions, and then integrate, verify, and validate the product or system. Together, these processes develop the system and establish the system's integrity. The Engineering process areas are:

- Requirements Development – elicits the needs, user requirements, system requirements, definition of the system functionality, identifies the interface requirements of the system, analyzes requirements, validates requirements, develops the concept of operations and scenarios for the system.
- Requirements Management – obtains an understanding of requirements, obtains and manages commitment to requirements, and manages the requirements themselves.
- Technical Solution – Develops alternative solutions and selection criteria, Evolves (elaborates) the concept of operations and scenarios, establishes interface descriptions, performs the make, Buy or Reuse Analysis, and develops the support documentation
- Product Integration – Determines integration sequencing, integration environment, manages interfaces, confirms the readiness for integration, perform integration.
- Verification – Selects work products for verification, verification environment, Verification Plans and procedures, perform verification, analyzes results.
- Validation – Selects work products for validation, validation environment, Validation plan and procedures, perform validation, analyzes results.

The engineering category also includes decision gate and technical review crosscutting activities that apply to each of the process areas. These activities are check points that ensure review of the deliverable products for quality and completeness before moving to the next project phase.

These core systems engineering processes are the focus of this evaluation and the focal point of Rule 23 CFR 940.11. The Department's Systems Engineering Guidebook for ITS, Systems Engineering training program, and this project have all served to raise awareness of the importance of good systems engineering processes within the Department.

Engineering – Overall Assessment

STRENGTHS AND WEAKNESSES	✚ **Districts and divisions are well aware of the value of requirements.** **<u>For ITS Field Equipment Projects</u>** ✚ **Many of the processes are performed in accordance with capital development processes.** Requirements development is performed as part of the planning and scoping phase, requirements management is embedded in the design documentation for the field elements. - **Completion is dependent on completion of the ITS application development.** Field equipment, (controllers, communications, and detection) implemented as part of a construction project may not be put into operations for many years, by which time, the equipment may need updating, repair or replacement. **<u>For ITS Application Development</u>** ✚ **Process areas performed on selected projects.** Requirements development and management are being performed on pre-CATMS and remaining process areas will be performed by the system integrator following pre-CATMS. - **No documented processes.** Information Technology Processes still in work. Processes will be relevant to ITS development, but are not completed. The draft process does not require commitment to requirements. The FSR and IT Project Oversight Framework are currently the only documented processes.
INITIAL ASSESSMENT & RATIONAL	**<u>ITS Field Equipment Projects</u>** Level 1 (Performing) - Requirements Development and Requirements Management are being performed. Many of the level 2 goals are met. (Plan the process, provide resources, Training, manage the configurations, stakeholder involvement, monitor and control, and review status.) ***The other process areas are incomplete.*** **<u>For ITS Application Development</u>** Level 0 (Incomplete) - Requirements Development and Requirements Management with some of the Verification are being performed at Level 1 on selected projects (Pre-CATMS) and many of the level 2 goals met, as with ITS Field Equipment projects. Other projects/areas are incomplete.
LEVERAGE *Existing Processes and Practices*	• DOF - Information Technology Project Oversight Framework and Feasibility Study Report requirements • DOT - Systems Engineering Guidebook for ITS • DOT - IT Systems Development Life cycle processes (under development) • Industry – EIA 632 Processes for engineering a system, IEEE 1220 Standard for the application and management of the systems engineering process, ISO 15288 Life cycle processes • Industry – ANSI/AIAA G-043-1992 Guide to the development of Operational concept document, IEEE 1362 Concept of Operations document • Industry – IEE Std 1233 Guide for the developing Systems Requirements Specifications, IEEE 1471-2000 Recommended Practice for Architectural Descriptions of Software Intensive systems.

Engineering – Process Area Assessment

PROCESS AREAS *Required and recommended areas*	+ **Requirements Management** — Required + **Requirements Development** — Required - **Technical Solution** — Required - **Product Integration** — Required - **Verification** — Required - **Validation** — Required + = *Performed* - = *Incomplete*
Requirements Management *Recommended improvements*	• *Establish a defined process for requirements management.* The process should address requirements baselining, require a commitment on baseline, and establish decision gates to support requirements buy-in. • *Requirements traceability is a key practice that should be addressed.* Traceability supports configuration management and system evolution.
Requirements Development *Recommended improvements*	• *Require identification of the requirements development process used* • *Process must include requirements analysis and requirements allocation.*
Technical Solution *Recommended improvements*	• *Alternative analysis is required by FHWA and DOF and should be a required practice.* Define criteria to guide common make, buy, or reuse alternatives analyses. • *Develop build-to design packages prior to implementation.* Include appropriate design reviews. • *The development of detailed interface descriptions will support the integration of the system*. Require documented interface descriptions for integration projects. Define a strategy/plan for the department on use of industry standards. • *Establish Guidance for Support Documentation Requirements.* Assure all products required to support operations and maintenance are developed and delivered. Manage this documentation using the configuration management process to keep it synchronized with the evolution of the system.
Product Integration *Recommended improvements*	• *Integration should be planned.* – The initial planning is done when the systems engineering plan is developed and updated when the detailed integration plan is completed at the detailed design stage. • *Establish the integration environment*. Project managers should consider resources and tools that will be required. • *Manage internal and external interfaces.* This is essential for the integration process as well as future evolution and upgrade.

Engineering – Process Area Assessment (cont.)

Verification *Recommended improvements*	• *Address Verification Planning.* Verification planning starts with a master plan developed as part of systems engineering management plan. Roles and responsibilities are defined and the verification environment is planned. The detailed verification plans should be developed as part of the requirements development and high level design. Verification procedures are developed as part of the development and readiness reviews.
Validation *Recommended improvements*	• *Address Validation Planning.* Validation planning starts with a master plan developed as part of systems engineering management plan. Roles and responsibilities are defined and the validation environment is planned. The detailed validation plans should be developed as part of the ConOps. • *The Department (system owner) is primarily responsible for validation, not the system integrator.* The system integrator is responsible for meeting the system requirements that have been approved by the Department of District.

2.3.4 Process Management

The CMMI Process Management process areas apply to the organization as a whole. Through this category, the organization establishes standard processes which individual projects tailor to their needs. There are five process areas in this category:

- Organizational Process Focus - Plan and implement organizational process improvement based on a thorough understanding of the current strengths and weaknesses of the organization's processes and process assets.
- Organizational Process Definition - Establish and maintain a usable set of standard processes for the organization.
- Organizational Training - Develop the skills and knowledge of people so they can perform their roles effectively and efficiently.
- Organizational Process Performance - Establish and maintain a quantitative understanding of the performance of the organization's set of standard processes in support of quality and process-performance objectives, and to provide the process performance data, baselines, and models to quantitatively manage the organization's projects.
- Organizational Innovation and Deployment - Select and deploy incremental and innovative improvements that measurably improve the organization's processes and technologies. The improvements support the organization's quality and process-performance objectives as derived from the organization's business objectives.

Process management is a key area for the Department. This category address the Departments framework for performing systems engineering. This is where the systems engineering policies or directives are created for planning and performing the processes. Currently the Department has a process focus that is part of the capital development culture and can be expanded to include the ITS developments.

Process Management – Overall Assessment

STRENGTHS AND WEAKNESSES	+ **The Department has strengths in all of the Process Management areas.** The gold book, maintenance processes, project management processes, training academies, etc. are ample evidence of the Departments capabilities and the high confidence in the development of capital projects. The ITS Field element projects also benefit from these processes. + **This Project, the Systems Engineering Guidebook for ITS, and Systems Engineering Training** reflect support for similarly integrating systems engineering processes into the Department's culture over time. - **Lack of consensus on how best to integrate the system engineering process for ITS within the capital development environment.** Capital developments and ITS projects have different processes, funding mechanisms, and constraints. Caltrans divisions disagree on the best approach and lines of responsibility. - **ITS Application development process uncertainty is compounded by the approval and programming processes that contribute to lengthy delays.** ITS project approvals can range from 2-5 years before a systems integrator is contracted. Lengthy delays encourage bypass/shortcutting of the process.
INITIAL ASSESSMENT & RATIONAL	**ITS Field Equipment Projects** Level 3+ (Defined) - Caltrans Headquarters provides excellent process management support for the districts. The department meets level 3 and supports practices associated with level 4 and 5. **ITS Application Developments** Level 0 (Incomplete) - This project and other efforts to provide Departmental-level support for ITS application developments are still in-work.
LEVERAGE *Existing Processes and Practices*	• DOF - Information Technology Project Oversight Framework • DOF – Feasibility Study Report • DOT - Systems Engineering Guidebook for ITS • DOT - IT Systems Development Life cycle processes currently under development. • Industry – EIA 632 Processes for engineering a system, IEEE 1220 Standard for the application and management of the systems engineering process, ISO 15288 Life cycle processes • Industry – Capability Maturity Model Integrated, SEI

Process Management – Process Area Assessment

PROCESS AREAS *Required and recommended areas*	**Organizational Process Focus** — Required **Organizational Process Definition** — Required **Organizational Training** — Recommended **Organizational Process Performance** — Future **Organizational Innovation and Deployment** — Future + = *Performed* - = *Incomplete*
Organizational Process Focus *Recommended improvements*	• *Complete the current systems engineering process improvement activities.* Through this project, the Department is currently performing an evaluation of the systems engineering process, identifying the needed processes and practices, and developing an action plan. Review, refine, and develop consensus around the action plan. • *Develop and deploy the process assets per the action plan.* Process assets include setting up a systems engineering organization, establishing a repository of templates, directives, documented processes and procedures, and systems engineering tools.
Organizational Process Definition *Recommended improvements*	• *Complete the life cycle model tailored for the Department.* Through this project, the Department is developing a life cycle model tailored for the Department. Review, refine, and develop consensus around the life cycle model. • *Define a candidate set of initial processes per the roadmap and apply it to candidate ITS projects as a pilot demonstration.*
Organizational Training *Recommended improvements*	• *Complete the update the SE fundamental course for ITS and renew SE Training*. The Department is currently in the process of developing and delivering systems engineering training. The previous version of the course was delivered from 2002 until 2004. • *Establish an ITS Academy that would include a number of ITS and systems engineering courses.*
Organizational Process Performance *Recommended improvements*	• *Establish performance measures for the process.* Through the pilot projects, establish a baseline.
Organizational Innovation and Deployment *Recommended improvements*	• *Deploy pilot processes in selected pilot projects, develop a set of measures, and analyze results.*

2.4 Relationships

Why talk about relationships?

Relationships are key to successful system development. Systems engineering is performed by integrated teams that frequently span more than one organization. In the current environment, simply getting approval for an ITS project requires working relationships within the department and between the department and other state and federal agencies. As discussed in section 2.2.4, the Team felt that relationships were important enough that this evaluation was expanded beyond a traditional CMMI evaluation to also specifically address organizational relationships.

How do we measure relationships?

The Team used a maturity model from the United Kingdom Ministry of Defense "Smart Acquisition" program that was developed for this purpose. Table 6 identifies the stages of maturity that are defined by the Smart Acquisition model. Appendix C contains the complete table that more completely characterizes each stage of maturity.

Table 6: Relationship Maturity Stages

Stages	Description
Beginning	Them & us
Developing	Respect & developing trust
Performing	Trust & joint goals lead to results
High Performing	Resilience to personnel changes, success spreads beyond key areas
Excelling	Model for others

The relationship between the FHWA and the Department for capital projects is a good example of a mature relationship. The Department is self certified for capital projects, which demonstrates the confidence that exists between the organizations for traditional capital development projects. One of the key goals of this project is to regain self certification status from FHWA for ITS projects. This will require FHWA to gain the same ***confidence*** that the Department has systems engineering processes in place and can perform them effectively for ITS projects.

This evaluation is based on observations from the interviews and project workshops. The Team recognizes that this area of the evaluation can be very subjective. The focus is on identification of organizational relationships that significantly impact the programming and development of ITS projects. One key question for this portion of the evaluation is:

> *Where does an organization need to be in its relationship with others to effectively program and develop ITS projects?*

2.4.1 Departmental (External) Relationships

In the course of ITS project planning, programming, and development, the Department interfaces with numerous external organizations. Figure 11 provides a birds-eye view of many of the key external relationships using a standard N^2 ("N squared") diagram. The figure is a matrix where each organization is named in the boxes on the diagonal and each circle represents a one way relationship between two organizations. Since each circle represents a one way relationship, two different circles are used to identify a complete two-way relationship. For example, D1 represents the relationship between the FHWA and DOT and A4 represents the relationship between DOT and FHWA in the figure. This representation allows the communications and information that is passed in each direction between the two organizations to be considered separately. The relationships between DOT and FHWA and between DOT and DOF deserve special attention and are described and evaluated in Table 7.

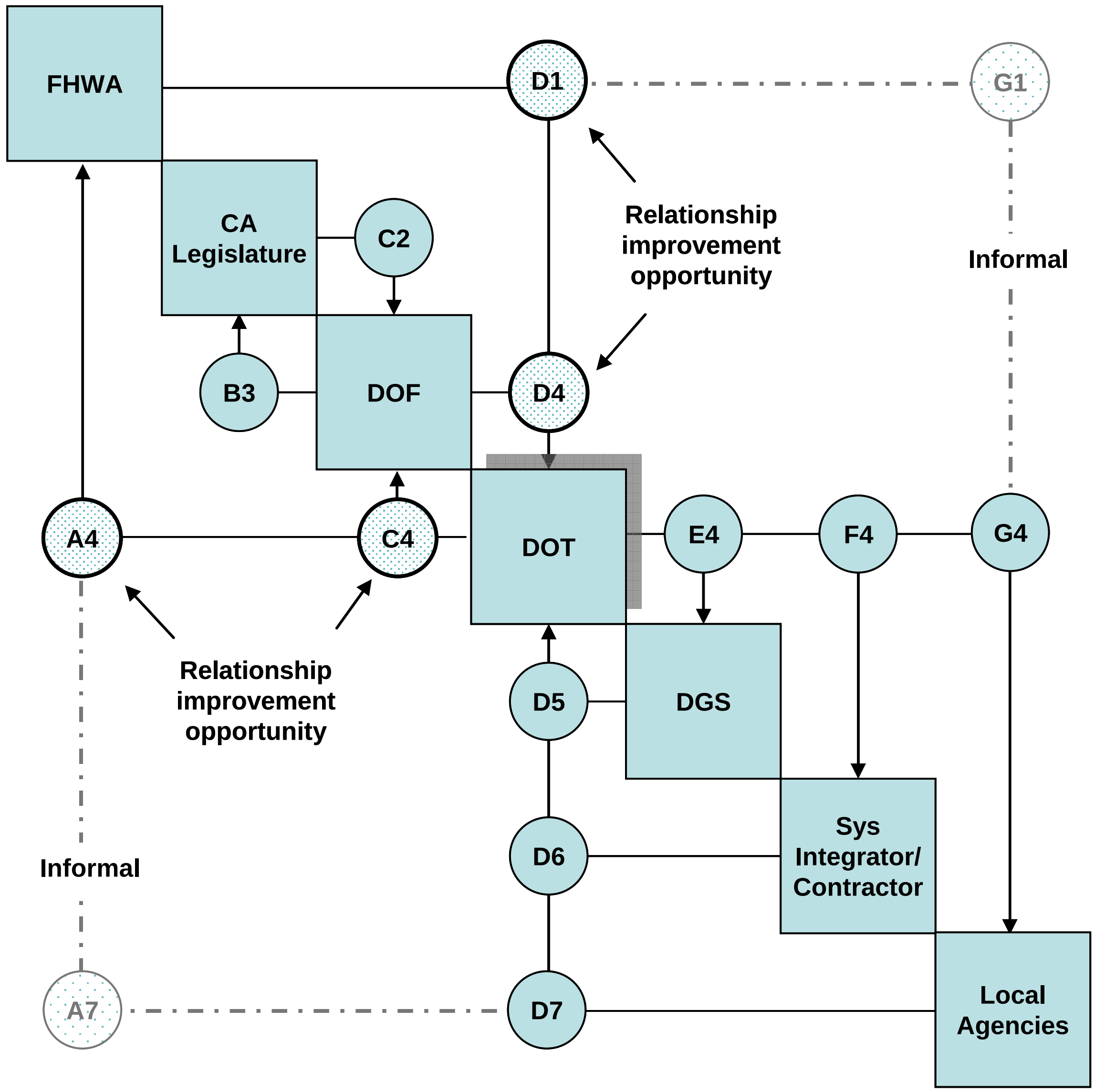


Figure 11: External Relationships for ITS Project Developments

2.4.2 Divisional (Internal) Relationships

During the interviews performed as part of the data collection effort, it was clear that the Caltrans divisions generally work well together, as an integrated team for the most part. Examples of good integrated team concepts and evidence of good inter-division relationships include:

- The established process of forming a cross-divisional Project Development Team (PDT) that ensures each division's interests and expertise are reflected into each project. Every division appeared to view the PDT concept favorably.
- The focus on stakeholder communications as a part of Project Management, exemplified by the Project Management Communications Handbook
- The nationally recognized Value Analysis process used by the department that includes the PDT in the process.

A few areas where inter-divisional relationships were reported to be challenges are identified in Table 8.

Table 7: Caltrans External (Departmental) Relationships Evaluation

Relationship		Description	Maturity	Rationale	Recommendation
DOT to FHWA A4	**Local Assistance**	The Department develops and maintains the Local Assistance manuals, guidelines, and procedures and sends these materials to FHWA for review, comment and approval.	***High Performing***	DOT works closely with FHWA to develop and maintain materials that support current regulations. The Local assistance documentation was updated to support 23 CFR 940 systems engineering requirements. There have been changes in staff with minimal impact in this area.	No further recommendations.
	ITS Project Development	Caltrans supports oversight for selected ITS projects by keeping FHWA appraised at selected points in the project programming and development process.	***Beginning***	The relationship is informal at this point with no formal mechanism for notifying FHWA of ITS projects that implement new functionality. FHWA division staff have identified a few ITS projects and included themselves into the process where necessary.	Jointly develop a documented procedure that supports FHWA oversight for higher risk ITS projects. The process can be reviewed and further streamlined as experience and confidence are gained.
FHWA to DOT D1	**Local Assistance**	FHWA establishes regulations for contracting, funding, project programming and development. FHWA division offices work with DOT, offering guidance and comments on local assistance program and materials. Also participates in training for new changes in the local assistance program.	***High Performing***	DOT works closely with FHWA to develop and maintain materials that support current regulations. The Local assistance documentation was updated to support 23 CFR 940 systems engineering requirements. There have been changes in staff with minimal impact in this area.	No further recommendations.
	ITS Project Development	FHWA established 23 CFR 940 Systems Engineering Requirements. FHWA division offices provide guidance on meeting the requirements. Oversight of individual ITS projects on an informal basis.	***Beginning***	The relationship is informal at this point with no formal mechanism for FHWA to provide systems engineering process-related input on higher risk ITS projects. FHWA division staff have identified a few ITS projects through happenstance and interjected themselves into the process.	Jointly develop a documented procedure that supports FHWA oversight for higher risk ITS projects. The process can be reviewed and further streamlined as experience and confidence are gained.

Table 7: Caltrans External (Departmental) Relationships Evaluation

Relationship		Description	Maturity	Rationale	Recommendation
DOT to DOF C4	**ITS Project Approval and Oversight**	The State Administrative Manual requires a formal relationship between DOT and DOF for approval and oversight of ITS Projects that are identified as "IT". An FSR must be submitted by DOT to support project approval for projects that exceed $500k. SPRs must be submitted for cost/schedule/technical changes. Project oversight reports must be provided periodically for medium and high criticality projects. A PEIR must be transmitted to close the project.	***Beginning***	DOT's formal line of communication to DOF is through the Division of Information Technology. This requires DOT divisions and districts to work through IT to first get their endorsement for ITS application development projects. Significant frustration and misconceptions about the current relationships were reported in the interviews with evident contention between IT, requesting division, and DOF.	Define the roles and criteria for ITS projects within the Department and between the Division of IT and the requesting Division. Work with DOF to dispel misconceptions. Establish a process within Caltrans that allows FSRs to be generated after the initial systems engineering analysis has been performed for ITS application projects.
DOF to DOT D4	**ITS Project Approval and Oversight**	The State Administrative Manual requires a formal relationship between DOT and DOF for approval and oversight of ITS Projects that are identified as "IT". DOF develops and maintains the IT Project Oversight Framework and guidance on the FSR and PIER documents, which are provided as guidance to the DOT. DOF reviews and approves FSRs, SPRs, and PIERs and provides oversight review of interim project reports for critical projects, providing feedback to DOT as necessary.	***Beginning***	Same as above	Same as above

Table 8: Caltrans Internal (Divisional) Relationships Evaluation

Relationship	Description	Maturity	Rationale	Recommendation
ITS System Owner Division to Information Technology (Bi-Directional)	Considerable debate within headquarters about the appropriate role of IT and other divisions in ITS application projects. This includes fundamental questions about the classification of ITS projects as IT projects. This appears to be more of an issue for headquarters than it is for the districts.	***Headquarters – Beginning*** ***Districts - Performing***	In most Districts, the Team found that the roles and responsibilities between the IT staff and ITS support staff were clear, and the staff worked well together. In a few Urban Districts there was no involvement of IT in the ITS support. At Headquarters the sense was that IT was encroaching in areas that were the domain of Traffic operations.	Clearly define the boundaries of the ITS systems and divisional roles and responsibilities. Better integrate IT and ITS support staff in planning, programming and developing ITS systems. Review processes used in other state DOTs (e.g., ODOT) where ITS and IT staff work together and complement each other's strengths.
Planning, Design, and Operations Divisions to Maintenance (Bi-Directional)	Maintenance is given field elements to maintain with no additional budget, training and tools. They have little input into the requirements.	***Beginning***	In the interview process, this issue came up a number of times. Also, policies on maintenance cycles change to extend the interval between equipment checks to reduce costs.	Maintenance should always be part of the integrated project development team and involved in the early stages of definition, development, and in the review of requirements for new ITS projects. Maintenance needs training tools and increased budgets that are linked to increasing ITS implementation.

3 Systems Engineering Model

A life cycle model that integrates the systems engineering approach into the Caltrans project development process is shown in Figure 12. The model addresses the FHWA 23 CFR 940 systems engineering requirements as well as the process requirements for IT projects that are levied by the State Administrative Manual. The lifecycle model aligns the capital development process activities, ITS project development activities, and the systems engineering process, represented by the "Vee" diagram at the bottom of the figure. Each of the major phases in ITS project planning, programming, and development are described in the following paragraphs. The model, and this section of the final report, is based on the model developed for the Department in the Systems Engineering Guidebook for ITS project Version 1.9. This initial model was updated based on the detailed evaluation of the Caltrans processes that was performed for this project.

The following sections provide a brief overview of some of the principles behind the lifecycle model followed by a brief description of each phase that is depicted in the model.

3.1 Key Observations

The following are key observations can be made for the Vee development model that is used as a basis for this lifecycle model.

1. The left side of the Vee is the definition and decomposition of the system into components that can be built or procured. The bottom of the Vee is the construction, fabrication and procurement or development of the component items. The right side of the Vee integrates the components into sub-systems and finally into the final system. Each level of integration is verified against the left side of the Vee through the Verification Plans (verification process)
2. A key objective of the systems engineering process that is strongly endorsed by FHWA and DOF is to push technology choices as close to the implementation as possible.
3. Decision gates provide the system owner with formal decision points to proceed to the next step of the process. A control gate is an interface from one phase of the project to the next and there is an interface between each phase on the left side to the right side.
4. There is a relationship of the activities performed on the left side of the Vee to the products produced, integrated and verified on the right side of the Vee (model versus system realization).
5. The view of the system that is most important for the system owner and stakeholders is at the Concept of Operations level. Below this level is the area of most interest to the development team and the area for which they are responsible (system owner responsibility versus the development team responsibility).
6. Importance of stakeholder involvement shows on the left side for defining the system and on the right side for the verification of the system.

3.2 Phase -1: Transportation Planning and Architecture Development

Before transportation projects are developed, a number of steps must be taken to ensure the right projects are developed based on local needs. The goal of the planning process is to make quality, informed decisions pertaining to the investment of public funds for regional transportation systems and services. The statewide ITS architecture and the regional ITS architectures developed for each metropolitan area are ITS-related tools that can be used to support these planning activities and reflect operations and maintenance considerations into the planning process. These planning activities are performed at the state level by the Division of Transportation Planning and by the RTPAs for each region.

3.3 Phase 0: Concept Exploration and Benefits analysis

Concept Exploration is used to perform an initial concept & benefits analysis and the elicitation of user needs and assessment of the needs for the candidate project concepts. This would result the identification of goals, objectives, vision, needs, benefits, cost/benefit analysis for the candidate concept that is recommended for development. At this stage, the highest cost/benefit project concept (best business case) is the one that should move forward into development. This stage may result in dividing the strategic projects or programs that are identified during the planning stage into location-specific projects that can be implemented incrementally based on the best cost/benefit analysis. It is recommended that the project team be formed at this phase of the project.   District 7 has formed a standing ITS integrated project team that takes an integrated view of transportation corridors to ensure that ITS elements are considered in the capital development process. The project development team should include stakeholders from operations, maintenance, design, and target users and division of IT. The project is than approved by DOT management and secures the funding to move forward into Phase 1 system engineering & project planning, and phase 2 systems definition.

3.4 Phase 1: Project Planning and Concept of Operations

Systems Engineering Management Plan (SEMP)

Each project that moves forward into development must be planned. This planning takes place in two parts. In part one, the system owner develops a set of master technical plans and schedules that identifies what plans are needed and the schedule for the implementation of the project. The SEMP will include the tailoring of the systems engineering process based on the perceived

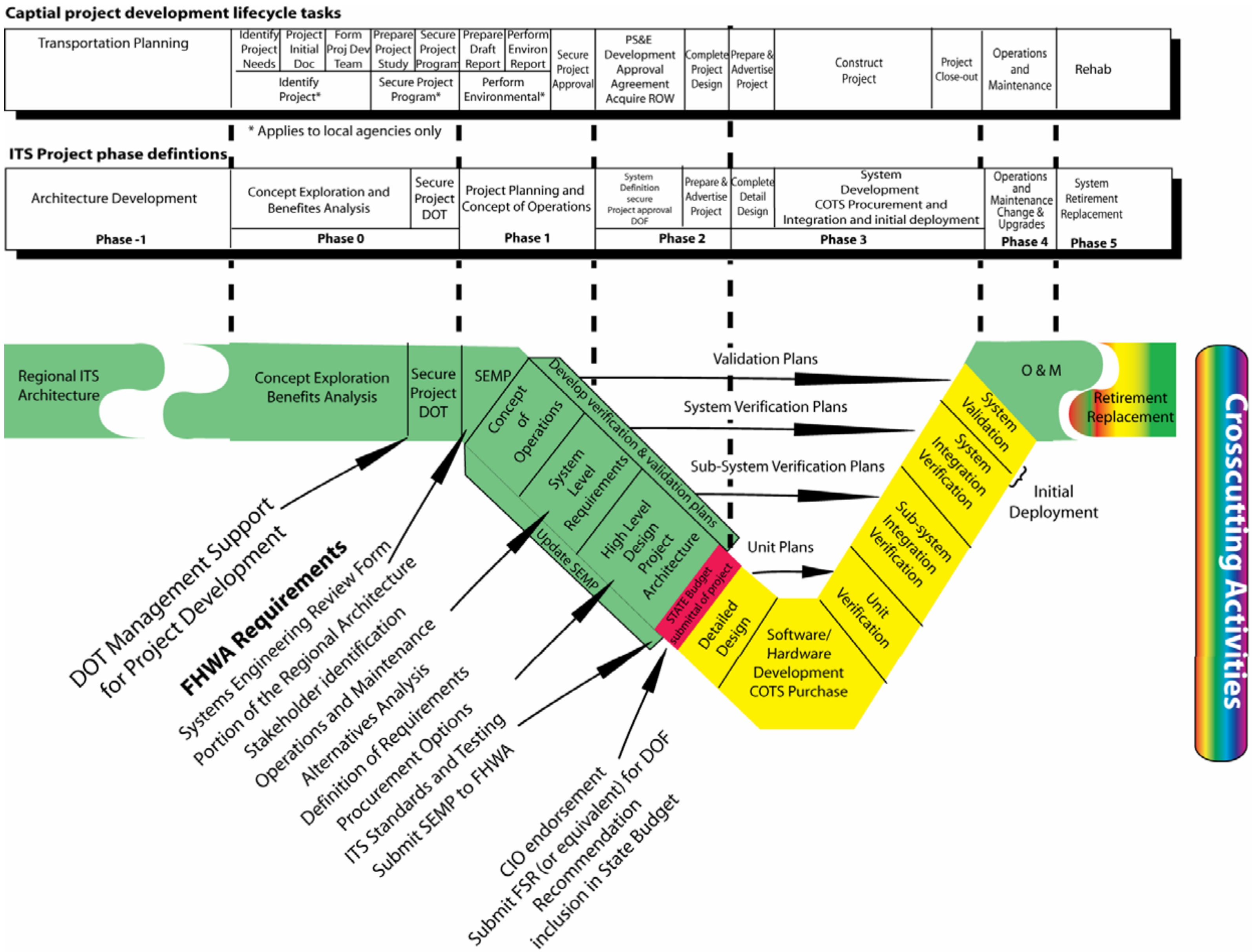


Figure 12: Caltrans Integrated Systems Engineering Lifecycle Model

project risks. This initial document is the SEMP framework (an annotated outline of the needed technical plans) and the master schedules for the project. The plans are completed during phase 1 & phase 2 of the project. These plans, once approved (at the end of phase 2) by the system owner, become the control documents for completion of the development and implementation of the project.

Systems Engineering Review Form (SERF)
The SERF will be completed for all ITS projects to verify compliance with 23 CFR 940. Pending coordinated discussions with FHWA, this form will be provided to FHWA for ITS projects that include new functionality or are otherwise agreed to be higher-risk projects. The framework for Systems Engineering Management Plan (SEMP) will also be started at this stage and completed at the end of phase 2. The SEMP will be provided to the FHWA on high risk ITS projects.

Concept of Operations
The Concept of Operations defines the way the system will be used in its intended environment. At this stage, the project team documents the way the envisioned system is to operate and how the envisioned system will meet the needs and expectations of the stakeholders. The envisioned operation is defined from multiple viewpoints for example, operators, maintainers, and managers, and how the system will be validated (proof that the envisioned system meets the intended needs). A refinement of the issues, needs, goals, expectations, stakeholder lists, and project constraints is placed into the concept of operations document. Concurrently to the development of the Concept of operation document, a validation plan is also developed. The plan defines the way the delivered system will meet the intended needs. (a technical plan defined in the SEMP). At this stage, the initial Operations and Maintenance plan required by the FHWA is drafted. This will be updated as with the other plans.

3.5 Phase 2 - System Level Requirements and High-Level Design

System Level Requirements
Requirements are developed for the system. At the system level, the requirements define precisely WHAT the system is to do, HOW WELL it is to do it, and under WHAT CONDITIONS are documented. The system requirements are based on the identified user needs from the Concept of Operations. Requirements do not state HOW (design statements) the system will be implemented unless it is intended to constrain the development team to a specific solution. Concurrently to the development of the system requirements document, a verification plan is also developed. The plan defines the way the delivered system will meet this set of systems requirements. (a technical plan defined in the SEMP). The decision gate for this step is the review and acceptance of the system requirements by the system owner.

High Level Design (Project Architecture) and Sub-system Requirements
The high level design stage defines the project level architecture for the system. The system level requirements are further refined and allocated (assigned) to sub-systems of hardware, software, databases and people. Requirements for each sub-system element are documented the same way as was done for the system level requirements. This process is repeated until the system is fully defined and decomposed. Each layer will have its own set of interfaces defined. Each layer will require an integration step that is needed when the sub-system is developed. Concurrently to the development of the sub-system requirements document, a verification plan is also developed.

The verification plan defines the way the delivered sub-systems will meet this set of requirements. (a technical plan defined in the SEMP). It may be discovered at this point that the estimates exceed the limits of the budget and the project may be a multi-year effort using an evolutionary deployment strategy. If this is the case, the information to DOF will need to reflect this and in subsequent years SPR's must be submitted for each evolution of the system functionality. The decision gate that is used for this final review is sometimes called the Preliminary Design Review (PDR). At the end of this stage the SEMP and Operations & Maintenance plan completed, Cost estimates are refined and the deployment strategy identified. The system owner and the sub-system owners must approve the requirements and the other stage products.

State Budget Submittal of the ITS Application Development Projects

The State legislature has deemed that any application software development and procurement of servers are considered IT projects and fall under the requirements of the SAM section 4800. In order to appropriate funds for the project, it must be identified in the State Budget. At this decision gate, the FSR documentation needed for the Department of Finance is compiled and submitted. The FSR content is a natural by-product of the work done to this point. The benefits, costs, and requirements have been reviewed and the deployment strategy has been defined at this step. This information is summarized and submitted to the Departments Chief Information Officer for approval and concurrence before sending it to the Department of Finance for their approval recommendation. Once identified in the State Budget, the project can precede to the phase 3 System Development. There will be a time lag from anywhere from 6 months to 18 months depending on the quality of information and timing of the submittal. All FSRs must be submitted to DOF by July, although the DOF has worked with various Departments to accept later submittals.

3.6 Phase 2- Prepare Procurement and Advertise Project.

At some level of risk, during the State Budget process for the ITS project, the system owner can proceed with the development of the Request for Proposals, Requests for Qualifications and enter into the procurement phase for the systems integrator. By using the systems engineering process, the system owner should have a high confidence the documentation submitted will be acceptable for DOF review and recommendation for inclusion into the state budget.

3.7 Phase 3 - Detailed Design and System Implementation

Detailed Design

At the component level detailed design step, the development team is defining HOW the system will be built. Each sub-system has been decomposed into components of hardware, software, database elements, firmware and/or processes. For these components, detailed design specialists in the respective fields create documentation ("build-to" specifications) that will be used to build or procure the individual components. A final check is done on the "build–to" specifications before the design moves forward to the actual coding and hardware fabrication. At this level the specific commercial off-the-shelf hardware and software products are specified but they are not purchased until the review is completed and approved by the system owner and stakeholders. The control gate that is used for this final review is sometimes called the Critical Design Review (CDR). During this step, unit test plans are development concurrently with the detailed design.

Hardware/Software Procurement or Development

This stage involves hardware fabrication, software coding, database implementation and procurement and configuration of off-the-shelf products. This stage is primarily the work of the development team. The system owner and stakeholders monitor this process with planned periodic reviews, e.g. code walkthroughs and technical review meetings. Concurrent with this effort, unit test procedures are developed that will be used to demonstrate how the products will meet the detailed design. At the completion of this stage the developed products are ready for unit test.

Unit Testing
The components from the hardware and software development are verified in accordance with the unit verification plan and detailed design. The purpose of unit test is to verify that the delivered components match the documented component level detailed design. This is done by the development team in preparation for the next level of integration. This initial level of integration is a good review point for the system owner and stakeholders as the system integrator prepares for the next several steps of integration/verification cycles.

Sub-system Integration and Verification
At this step, the components are integrated and verified at the lowest level of the sub-systems. The first level of verification is done in accordance with the verification plan and is carried out in accordance with the verification procedures (step-by-step method for carrying out the verification) developed in this stage. Prior to the actual verification a test readiness review is held to determine the readiness of the sub-systems for verification. When it is determined that verification can proceed, the sub-systems are then verified. When the integration and verification is completed, the next level of sub-system is integrated and verified in the same manner. The process continues until all of the sub-systems are finally integrated and verified.

System Verification
System verification is done in two parts, the first part is done under a controlled environment (sometimes this is called a “factory test”) and the second part is done in the environment in which the system is intended to operate (sometimes called “on-site testing”) and is done after initial system deployment. At this stage the system is verified in accordance with the verification plan developed as part of the system level requirements done earlier in the development. The system acceptance will continue through the next stage, initial system deployment. The final part of system verification is then completed. A control gate is used for this conditional system acceptance.

Initial System Deployment
At initial system deployment, the system is finally integrated into its intended operational environment. This step may take several weeks to complete to ensure that the system operates satisfactorily long term; this is sometimes called a “system burn-in”. Many system issues will surface when the system is operating in the real world environment for an extended period of time. This is due to the uncontrollable nature of inputs to the system, long term “memory” leaks in software coding and race conditions. Conditions that may only occur under specific and infrequently situations may cause the system to fail. Once the system verification is completed, the system is accepted by the system owner and stakeholders and moves into system validation and operations and maintenance phases.

System Validation
Validating the system is a key activity of the system owner and stakeholders. It is here that they will assess the system’s performance against the intended need, goals and expectations as documented in the Concept of Operations and in the validation plan. It is important that this validation takes place as early as possible after the acceptance of the system in order to assess the strengths and weaknesses and assess new opportunities. As a result of the validation new needs and requirements may result. This activity does not check on the work of the system integrator or component supplier (that is the role of system and sub-system verification) and is performed after the system has been accepted. As a result of validation, new needs and requirements may be identified. This evaluation sets the stage for the next evolution of the system.

3.8 Phase 4- Operations and Maintenance

After the initial deployment and system acceptance, the system moves into the operations and maintenance phase. In this phase, the system will carry out the intended operations for which it was designed. During this phase, routine maintenance is performed as well as staff training. This phase is the longest phase since it will extend through the evolution of the system and end when the system is retired or replaced. This phase may carry on for decades. It is important that there are adequate resources to carry out the needed operations and maintenance activities; otherwise, the life of the system can be significantly shortened due to neglect.

Changes and Upgrades

During the operations and maintenance phase, if changes and upgrades are needed, it should be done in accordance with the Vee technical process. Using the Vee process for changes and upgrades will help maintain system integrity (maintain synchronization between the system components and its respective documentation). Sometimes existing systems (legacy systems) have not been well documented. In such cases, it is recommended to first perform a reverse engineering process on the target areas of proposed change in order to develop the needed documentation for the forward engineering process. Depending on the changes and upgrades, DOF and FHWA process will be required for new functionality.

3.9 Phase 5- Retirement/Replacement

At some point in the life of a system, it may be necessary to retire and/or replace the system. The system may no longer be needed, may not be cost effective to operate, may no longer be maintainable due to obsolescence of key system elements or this may be a planned activity where an interim system was put in place for a period of time until the final system was ready for deployment. This stage looks at how to monitor, make the decisions needed and prepare for this event.

3.10 Cross-Cutting Activities

The following are cross cutting activities that will apply to one or more steps in Systems Life Cycle model for the Department of Transportation's ITS projects. This will also clarify some of the terminology in the description of the steps of the process.

Stakeholder Involvement

Stakeholder involvement is regarded as one of the most critical enablers within the development and life-cycle of the project and system. Without effective stakeholder involvement, the systems engineering and development team will not gain the insight needed to understand the key issues and needs of the system owner and stakeholders. This will increase the risk of not getting a valid set of requirements to build the system or to get buy-in on changes and upgrades. Key stakeholders will change depending on the phases of the life cycle. For example, in phases 0-2 the IT management is a key stakeholder, since they need to endorse the project prior to DOF submittal. Operations & Maintenance is critical throughout the phases since at the end of the project it will need to meet their needs.

Elicitation

Elicitation is the act of effectively and accurately gathering information needed to develop the system. Needs, goals, objectives, requirements, and other information are obtained by a discovery process. Some of the information is documented or otherwise clearly stated but much is implied or assumed. This enabling process helps draw out and resolve conflicting information, build consensus, document and validate this information.

Project Management Practices
Various project management practices are needed to support the development of the system. Project management practices provide a supportive environment for the various development activities. It provides the needed resources, then monitors and controls cost, schedules and communicates status between and across the development team members, system owner and stakeholders.

Risk Management
There will be risks for ITS system development efforts. Risk Management is a process used to identify, analyze, plan, monitor and then to mitigate, avoid, transfer or accept these risks.

Project Metrics
Project metrics are measures that both the project manager and the systems engineer use to track and monitor the project and the expected technical performance of the systems development effort. The identification and monitoring of metrics are important so that the team can determine if the project is “on-track” both programmatically and technically.

Configuration Management
Managing change to the system is a key process that occurs throughout the life of the system. Configuration management is the process that supports the establishment of system integrity (the documentation matches the functional and physical attributes of the system) and maintains this integrity throughout the life of the system (synchronizes changes to the system with its documentation). The lack of change management will shorten the life of the system and may prevent a system from being implemented and deployed. This is established during phase 1 of the project and carries through the life of the systems life cycle. This is the only process that carries on past the development phase. It must be in place through the evolution, changes and upgrades and the retirement and or replacement of the system.

Procurement Options
Procurement options are important for the system owner and stakeholders. The goal in choosing a procurement option is to give the system owner the greatest flexibility and to manage project risk appropriately. The choice depends on the phase of work being done. Some phases of work will lend themselves better to one type of procurement option over another. This is a requirement of the FHWA rule of looking at alternative procurements.

Deliverables/Documentation
Examples of products are identified as one would expect from each phase of the development and system lifecycle. Asking for the appropriate documentation at the appropriate level of quality will drive the quality of system that will be delivered.

Process Improvement
A quality aspect of the systems lifecycle is to continuously improve the process and to learn from previous efforts to improve future work that may be done. Process improvement is an enabler that will provide insight on what worked and what needs improvement in the processes. This activity is used to improve the system owner’s and development team’s documented processes over time.

Decision Gates
Decision Gates are formal points along the lifecycle that are used by the system owner and stakeholders to determine if the current phase of work has been completed and that the team is ready to move into the next phase of the lifecycle. By setting entrance and exit criteria for each phase of work, the control gates are used to review and accept the work products done for the current phase of work and also evaluate the readiness for moving to the next phase of the project.

Trade Studies
Technical decisions on alternative solutions are a key enabler for each phase of system development. This starts when alternative concepts are evaluated, and continues as requirements are decomposed and allocated to sub-system developing, the high level design is developed and commercial off the shelf products are assessed. This section provides a method to perform a trade study. There is both a requirement from the SAM and FHWA to look at alternatives.

Technical Reviews
Technical reviews are used to assess the completeness of a product, identify defects in work, and align the team members to a common technical direction. This section provides a process for conducting a technical review.

4 Roadmap for Implementation

The roadmap is a set of recommendations that builds on the previous sections of this report. In section 2, the current Caltrans processes were evaluated (“where we are now”). In section 3, a target systems engineering lifecycle model was defined that addresses DOF and FHWA requirements and is consistent with existing Caltrans processes (“where we would like to be”). This section provides recommendations for progressing Caltrans systems engineering processes and capabilities from where they are now to where they should optimally be.

The recommendations are divided into 3 sections:

4) Systems engineering capability enhancements and process improvements
5) Organizational enhancements to create an environment for systems engineering to work
6) Tailoring of the life cycle processes to integrate the activities of both the Highway & Intelligent Transportations Systems together.

These recommendations build on an excellent start that the department has already made in systems engineering process improvement. For example, the Intelligent Transportation Systems Interdepartmental Coordination agreement, signed by most divisions and the District 4 director, provides critical management support and visibility for the recommended process and capability improvements. It is the foundation for the departmental policy, organizational enhancements and allocation of responsibilities, process definition and integration, and staff capacity building that are recommended in this section.

4.1 Capability and process improvements

Table 9 illustrates the Team’s recommended three phase program systems engineering process improvement for the Department. The process improvements are staged so that the process areas that are most critical to Caltrans are accelerated and addressed in the earlier phases.

1. Phase 1 process areas address a broad set of fundamental system engineering processes. Included in this set of processes are those required by the FHWA Final Rule and the DOF Project Oversight Framework. Once the phase 1 process improvements are complete, the required practices will all be performed at the project level. This offers an opportunity to use a pilot project to evaluate the processes on real projects prior to establishing Department-wide directives for them.

2. Phase 2 builds on the phase 1 set of capabilities to include a higher level of maturity for the process areas. This level would establish organizational policies, plan the processes, train people, manage configurations, and objectively evaluate the processes. With the phase 2 improvements, the systems engineering processes would be broadly implemented and managed in projects across the organization

3. Phase 3 builds on phases 1 and 2 and establishes and institutionalized the set of processes within the organization. At the end of phase 3, the systems engineering processes will be as well documented and as much a part of the Department’s culture as the capital project development processes.

Rather than try to implement process improvements across all projects at the outset, it is recommended that the department identify one or more pilot projects that will allow experience to be gained and lessons to be learned prior to broader roll out systems engineering process improvements. A pilot project will be selected to implement the process areas at the specified level of capability. The pilot projects will actually require some additional schedule and resources to focus on process and support data collection about the process improvements and evaluation of the process's impact on project performance.

Table 9: Systems Engineering Process Improvement Roadmap

Phase			Category/Process Area/Specific Practices
1	2	3	
Target capability level			**Engineering Processes**
1	2	3	Requirements Development
1	2	3	Requirements Management
1	2	3	Technical Solutions
1	2	3	Product Integration
1	2	3	Verification
1	2	3	Validation
			Project Management
2	3	4	Project Planning
2	3	4	Supplier Agreement Management
2	3	4	Integrated Project Management
2	3	4	Risk Management
2	3	4	Integrated Teaming
X	1	2	Integrated Supplier Management
X	X	1	Quantitative Project Management
			Support
1	2	3	Configuration Management
1	2	3	Process and Product Quality Assurance
1	2	3	Measurement & Analysis
1	2	3	Organizational Environment for Integration
1	2	3	Decision, Analysis & Resolution
X	1	2	Causal Analysis & Resolution
			Process Management
2	3	4	Organizational Process Focus
2	3	4	Organizational Process Definition
2	3	4	Organizational Training
1	2	3	Organizational Process Performance
1	2	3	Organizational Innovation & Deployment
			Acquisition Best Practices
2	3	4	Solicitation and Contract Monitoring
2	3	4	Transition to Operations and Support

The initial process improvement activity is to document a set of process procedures for project use. The work that the Division of Information Technology has done with their current process development efforts could be used as a starting point.

1) Prior to the project, the staff will be trained on the process areas to be piloted. The integrated project team will establish process goals and specific practices for each process area. The

team will review the process procedures and tailor them to establish a baseline set of processes to use for the pilot project.

2) During the project, process improvement information should be kept and reviewed with the integrated project team on regular periodic meeting times (weekly/monthly) to develop a lessons learned log. This log will be used to assess the effectiveness of the process and tailoring.
3) At the end of each project phase, the processes that were used will reviewed, strengths and weaknesses will be identified, and then course corrections will be made if needed.
4) At the end of the project, the lessons learned and recommendations for the processes used will be documented.

The pilot project process should be repeated for several projects with different characteristics. The case studies developed for each pilot project will serve as examples that future projects can use. The pilot project case studies should be archived and accessible for all project managers in the Department.

4.2 Organizational Recommendations

Organizational enhancements will provide an environment for systems engineering to mature and to improve over time. The organizational enhancements will address one of the most important keys to success – management support for system engineering. The organizational recommendations are:

5) Set up a Systems Engineering organization that would manage the systems engineering process and provide expert assistance. (phase 2)
6) Establish an ITS Academy – include systems engineering, requirements, Configuration management, design, ITS project management and technology topics. (phase 2 & 3). This has to potential to be a model for other states and could be premiere center for training ITS and systems engineering and project managers in ITS.
7) Establish an ITS technology center – Create a forum for the discussion of technologies with ITS practitioners from around the state. (Phase 3) – This would allow the key ITS technologist to work together and collaborating on ITS technology, standards, and other key issues.
8) Establish an on-line systems engineering repository that includes systems engineering directives, best practices, templates, processes, guidebooks, case studies and tools (such as requirement management, modeling, and decision support tools). The repository would be a resource that project managers and project systems engineers could access and use.(phase 1-3)

4.3 Integrating Systems Engineering and Capital Development Processes

Figure 13 is an integrated view of the ITS project and capital development project life cycles. By leveraging the parallels in the two lifecycles, a single process can be defined that supports both Capital Development and ITS projects that diverge only where funding or approval requirements dictate.

4.3.1 Capital and ITS Lifecycle Comparison

The key integration aspects of the two lifecycles include:

1) Phase -1 is the long range planning activities performed by the Division of Transportation Planning. ITS is increasingly mainstreamed in the transportation planning process as planners take a corridor view and management and operations is increasingly incorporated into planning, per SAFETEA-LU.
2) Phase 0 - ITS activities mirror the capital development activities. For both types of projects, the objective is to look at alternative concepts and make the business case for the project. ITS Field element projects will proceed through the capital development processes and ITS application development projects will need management support and approval to carry these projects into the next phase of work. Preliminary costs and schedule are provided.

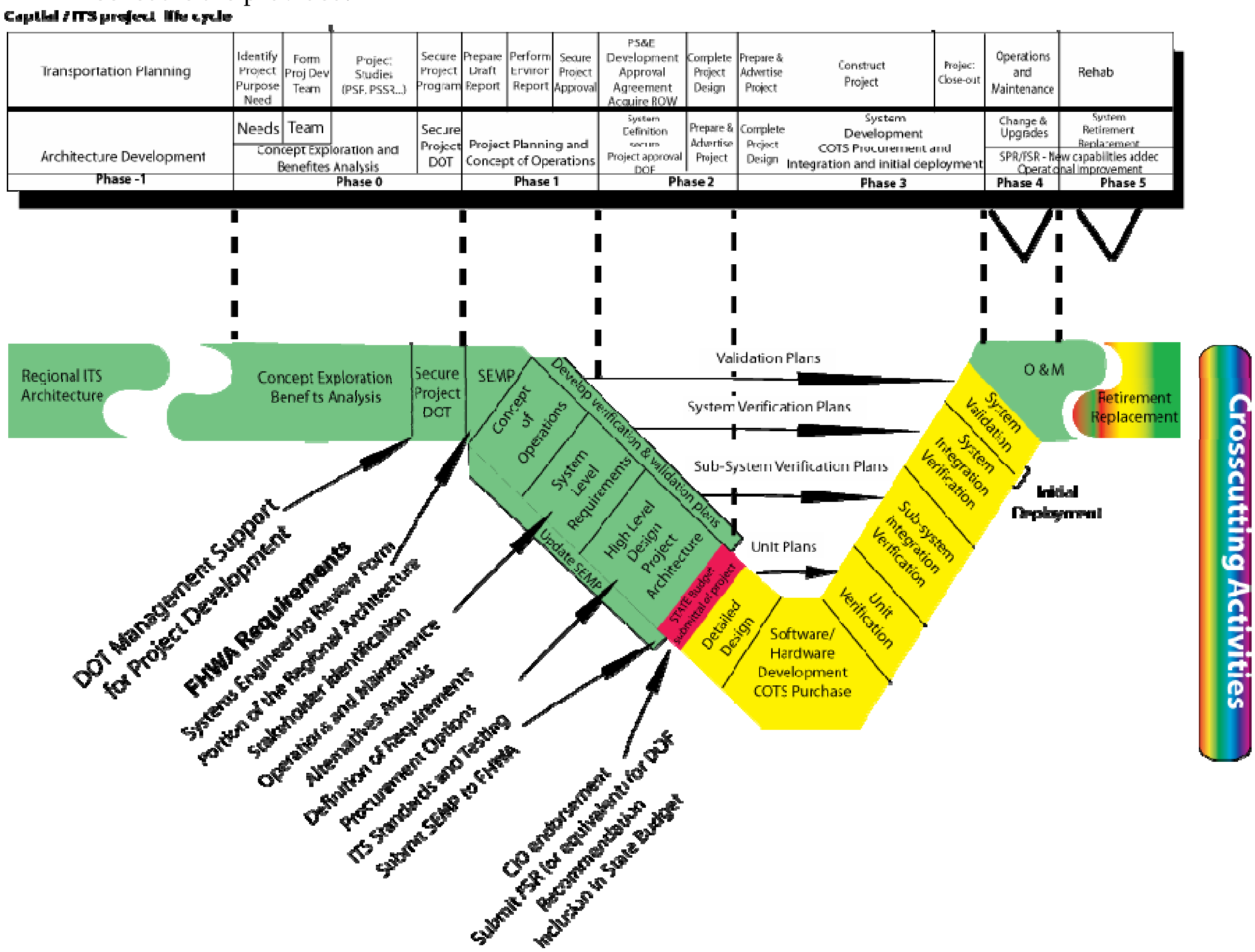


Figure 13: Integrating the Systems Engineering and Capital Development Processes

3) Phase 1- The Systems engineering plans are developed and the concept of operations and validation plans are developed with critical involvement from the system owners, affected users, and other stakeholders. Participation by ITS specialists and systems engineers is analogous to the preliminary engineering and studies that are performed for capital developments. The project development team can include the ITS specialists just as it includes environmental experts for capital development projects.
4) Phase 2 –Defines what the Intelligent Transportation System is to do to a level that a system integrator can design, implement, and deliver the system. This corresponds with the development of PS&E for capital development projects. For ITS application projects, an FSR will be generated that summarizes the requirements, costs, benefits, and other artifacts of the systems engineering process. The FSR will be processed through the internal Caltrans signature cycle through the CIO and then the FSR will be sent to the

DOF for approval. The difference between the capital development process and ITS development is that at this point the procurement for a system integrator needs to start. The system integrator for ITS projects must perform the detailed design in addition to the construction of the hardware and software.

5) Phase 3 is the systems development phase where the system integrator would design, construct, implement and verify the system. System validation is performed and the system is ready to transition into operations and maintenance. This would correspond to the construction phase of capital development process to close out.
6) Phase 4 is the operations and maintenance phase – Operations & maintenance for ITS and capital projects would now fall under the State legislative policies for funding of O&M, and upgrades. If the FSR covered additional functionality to be added to the system over time, Special Project Requests would be needed for each evolution of the systems capabilities. At the completion of the final incremental project, a PEIR is completed to close out the project. Additional functionality would require a new FSR.
7) Phase 5 retirement and replacement, would require a new FSR repeating the cycle for system replacement. The key point is that if the system engineering process is used, the information that is included in the FSR is a natural byproduct of the process.

One of the key findings of the data collection effort was the different approval requirements for different types of ITS projects and yet another set of processes and requirements associated with operations and maintenance funding that must be addressed.

1) DOF is involved with operations and maintenance when Budget Change Proposals (BCP) are issued for increases to O&M budgets. For example, adding ramp meters to existing systems, maintaining roadways, and maintenance of ITS field elements are all considered operations and require DOF review for budget increases.
2) New capital development projects are funded through SHOPP, STIP and require CTC approval.

These issues have implications on the integration of the model.

4.3.2 Integration Recommendations

The following initial steps are recommended to integrate systems engineering into the capital development process.

5) Perform Phases 0-2 of the ITS project development as part of the capital development process, funded through the STIP/SHOPP like capital development projects. ITS Field element projects would continue through the capital development process and the ITS Application development would proceed until the end of phase 2.
6) In phase 0, form Integrated Teams that address ITS projects as part of corridor routes (already being implemented). Include Division of Information Technology, Maintenance (TMC Support, Electrical Maintenance).   Use District 7's model for the integrated team as a starting point.
7) Involve the FHWA ITS staff in the Concept phase and then at the decision gates for phases 0-3.

Rationale:

There is no requirement for an FSR to do studies or the analyses in Phases 0-2. These phases can be performed without involvement of DOF or securing funds through the FSR process. Using this approach, this process is under the control of the Department while the basic systems analyses are performed. The products from phases 0-2 provide the information needed for the FSR. As a result of the systems engineering analysis, the project scoping, requirements, benefits and cost estimates will be refined as much as possible without doing the actual design.

Many of these initial integration steps are already being implemented in some form. For example, District 7 has formed an standing ITS integration team that is involved in the identification of the ITS elements that would be implemented in corridors. The Department is also developing a check list for mobility corridors that will include ITS aspects. The pre-CATMS project that is currently underway will produce a systems requirements specification.

8) Recommendation is to structure artifacts from the end of phase 2- to be used for FSR information, summarize and tailor the artifacts from the process to produce the equivalent to the FSR. Structure projects performing phase 0-phase 2 by the end of May.

Rationale:
For ITS application development projects, timing of the required information into the state budget is critical. DOF needs the information by July to be included into the next State budget. Although DOF has worked with the Department to extend this deadline, it is a target for future projects of this type. At the end of phase 2 the project scoping will be well defined and the deployment strategy understood. For example, at the end of phase 2, it was found the project needs to deploy in an evolutionary deployment strategy over several years. This can now be reflected in the DOF information as a roadmap for several subsequent projects that would be well understood by DOF.

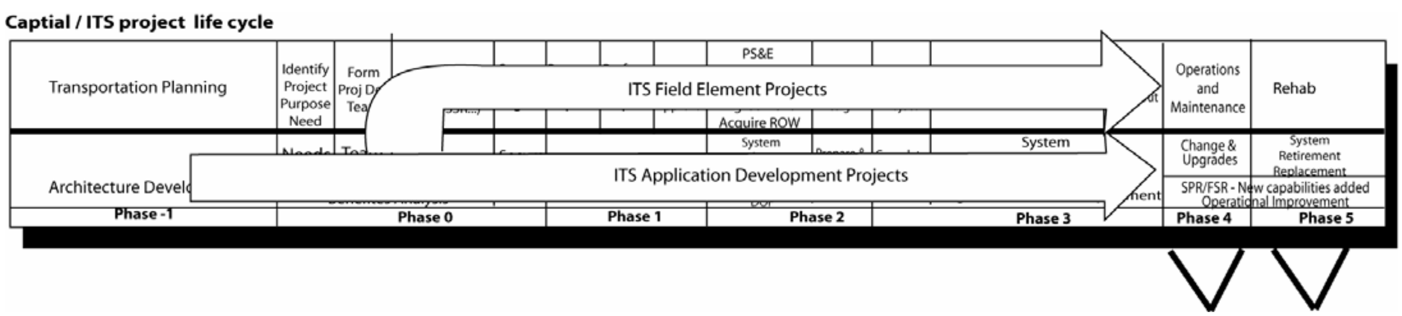


Figure 14: Life cycle with identified paths for ITS field element and ITS Application projects

The figure illustrates the divergence of ITS projects into two paths, one for the field elements and one for application development. The processes are very similar; both apply systems engineering processes and principles. Both paths are unique since each project includes a different set of artifacts to realize their system of interest. Each path has a unique set of skills and disciplines to enable the development of their respective systems. This is true of any multi-disciplinary effort. For example, Aircraft & Air Traffic Control systems, Rockets & Satellite Systems, Mechanical & Electronic systems, Highway & Intelligent Transportation Systems each will have their unique processes to develop systems that are ultimately integrated. In each case, it is the system engineer's responsibility to integrate these disciplines and processes together to realize successful systems.

Appendix A: List of Documents Collected

Table 10: List of Collected Documents

Documents
Information Technology
High Critical WBS
Product Descriptions v3_3
SDLC Deliverables1_r6
SerfSempv1_0
Example FSR (California Film Commission Film Permitting System)
1. FPS FSR Transmittal final.doc
2. FPS FSR Project Summary Package final.doc
3. CFC FPS FSR final.doc
4. CFC FPS EAW's final.xls
5. FPS FSR Attach #1 final.doc
6. FPS FSR Attach #2 final.doc
7. FPS FSR Attach #3 final.doc
8. FPS FSR Attach #4 final.doc
Appendix_g_instr_2-25-04.doc
Information technology project summary package section a: executive summary
FRS preparation Instructions
Feasibility Study Report Reporting Exemption Request (preparation Instructions)
Post-Implementation Evaluation Report (preparation Instructions)
Introduction to Information Technology project reporting (preparation Instructions)
Special Project Report (preparation Instructions)
Information Management Cost Report (preparation Instructions)
IT Oversight Framework
Project Manager Notes on the Preparation of a Project Charter
Summary of Changes to SAM 4800 – 5180 -June 2003
Summary of required information
Previous version of the IT SDLC process description
Application Development and Maintenance Methodology (AD&M)
IntegWBS_v2_4.mpp
Division of Design
Project Development Procedures
Resource Breakdown Structure
How Caltrans Builds Projects
Local Assistance
Local Assistance Procedures Manual
Local Assistance Procedures Guidelines
Consultant Selection Guidebook
Emergency relief guidebook
Transportation Funding Opportunities Guidebook
Division of Research and Innovation
Deputy Directive 81
RI Functional Org Chart 6.18.04
Project Selection Process As-Is
Systems Engineering Guidebook for ITS
Division of Project Management
Project Management Handbook

Table 10: List of Collected Documents

Documents
Risk Management Handbook
Communications Handbook
Division of Transportation Systems Information
Travel Household survey Report
2003 California Public Road Data
Highway Performance Monitoring System Update Instructions
LRS State Highway Data Model Project Data Maintenance Documentation
LRS State Highway Data Model Project Data Maintenance Procedures
LRS State Highway Data Model Project Data Construction Documentation
Guidelines for Applying Traffic Micro simulation Modeling Software
Checklist for placing data into GIS Library
Conflation correction work flow
Core Dynseg Business Logic
CRS mapping QC
HPMS Process
Anno editing rules
Functional Classification & CRS Map Flowchart Highway System Engineering
FUNC – GDT Conflation Project Work Flow
Highway Performance Monitoring System (HPMS) Field Review Guidelines
CRS Map, HPMS Report, and FUNC Update Process
Functional Classification Guidelines
Travel Forecasting and Analysis
Validation Requirements
Division of Construction
Red book (Construction Manual)
Constructability review policy on-line website
Division of Traffic Operations
TMS Master Plan
Business Continuity Planning fo Transportation Management Centers
Traffic Operations Strategies (TOPS)
TMS Standardization Plan
CHIN Business Process Review Project Reports (Improvement Opportunities and Gap Analysis, Consumer & Systems Requirements, Baseline Assessment, Implementation Plan, Solution Recommendations)
Traffic Operations Management Business Process Review
Division of Transportation Planning
Overview of Caltrans Transportation Planning Activities
Bible for Transportation Planning Managers
Transportation Planning Academy manual
California Department of Transportation 2005/2005 Program Level Action Plan
GoCalifornia Presentation (Downloaded from the Web)
Intelligent Transportation Systems (ITS) Mainstreaming Charter
Intelligent Transportation Systems (ITS) Interdepartmental Coordination
Unleashing Technology's Benefits in California Transportation System
Updated Vee model
Division of Environmental Analysis
Website (downloaded) Environmental process Documentation
Volume 1 chapters 1-6 and 37

Table 10: List of Collected Documents

Documents
Division of Maintenance
Chapter K - check lists, Quality of Service
Value Analysis
Value Analysis Program Overview
Value Analysis website
Industry Sources of Information
CMMI Maturity Model
Staged
Continuous
Standard CMMI Appraisal Method for Process Improvement (SCAMPI) Version 1.1
Appraisal Requirements for CMMI Version 1.1 (ARC, V1.1)
Acquisition Standardization Maturity Model May 2002. UK Defense Standardization
CMMI V1.1 and Appraisal Tutorial – Mike Phillips CMMI Manager Software Engineering Institute
Various supporting Assessment and Acquisition maturity model materials
The CEO Guide to IT Value@Risk
CobiT Primer
Cobit 4.0
Aligning CobiT, ITIL and ISO 1779 for Business Benefit
ITIL basics
ISO 15288
EIA 632
IEEE 1220
MitreTek - Monographs
Systems Engineering
Requirements
Configuration Management
Other Agency Documentation
Office of Systems Integration – Best Practices (download from website)
Office of Systems Integration – Policies
Office of Systems Integration – BP Project Management Reference
Office of Systems Integration – BP Requirements Management Reference
Office of Systems Integration – Schedule work plan Management Reference
Office of Systems Integration – Various Plans and tailoring templates
Office of Systems Integration – DID’s Project Management Plan
Office of Systems Integration – Various Guides
General Services – State Administration Manual – 4800 & 5200 chapters of IT
Compliance Analyzers – SW-CMM, Policy, SA-CMM

Appendix B Capability Maturity Model Integration (CMMI)

The following description of CMMI was originally develop as part of the Caltrans Systems Engineering Guidebook for ITS and modified for this report.

What is CMMI? Capability Maturity Model Integration (CMMI) is a way to evaluate the maturity level for system engineering within an organization. CMMI along with the assessment tools e.g. SCAMPI & ARC. CMMI and the assessment tools were developed by industry.

Background:
The following is an excerpt from CMMI Distilled: A Practical Introduction to Integrated Process Improvement, a SEI Series textbook in Software Engineering, by Ahern, Clouse, and Turner which was published by Addison-Wesley in 2001.
"Model-based process improvement involves the use of a model to guide the improvement of an organization's processes. Process improvement grew out of the quality management work of Deming[1], Crosby[2], and Juran[3] and this work was aimed at increasing the capability of work processes. Essentially, process capability is the inherent ability of a process to produce planned results. As the capability of the process increases, it becomes predictable and measurable, and the most significant causes of poor quality and productivity are controlled or eliminated. By steadily improving its process capability, the organization matures".
The early 1990's saw a proliferation of models for process assessment that included: acquisition, people, security, integrated product development, software, systems development, and project framework, in addition to ISO 9000 series. This created a quagmire of process standards and quality models [for more information go to http://www.software.org/quagmire]. To eliminate inconsistencies, duplications, and provide a common framework, terminology and focus, Capability Maturity Model Integration [CMMI] was initiated by the U.S. Department of Defense and the National Defense Industrial Association [NDIA] in 1997. They teamed with the Software Engineering Institute at Carnegie Mellon to integrate the pertinent models for systems development together into a single model. It is called Capability Maturity Model Integration [CMMI]. The CMMI model uses source material from Software [SW-CMM, draft version 2c], Systems Engineering [EIA/IS 731], and integrated product and process development [IPD-CMM, version 0.98]. The team that put CMMI together included authors from the source models and other key industry experts. The final version was completed in 2000...To download the latest version of CMMI for free, go to http://www.sei.cmu.edu/cmmi/. CMMI is the model superseding previous assessment tools such as SW-CMM and systems engineering EIA 731.

Figure 1 below illustrates how CMMI has integrated the best practices from source material into 24 Process Areas [EIA 731 has 19 of these and calls them Focus Areas] or *best practices*. In CMMI these process areas are divided into four categories as illustrated. These process areas cover the "waterfront" of *best practices* needed for systems development. The graphic illustrates how processes support the next level up. The Process Management at the Enterprise level supports the Management processes for the program and project level. The Management processes, in turn, support the engineering processes at the project level. Cross-cutting processes that support all levels are on the left side.

[1] Deming, W. Edwards, *Out of the Crisis*, Cambridge, MA; MIT Center for Advanced Engineering, 1986

[2] Crosby, P.B. *Quality is Free*. New York: McGraw-Hill, 1979

[3] Juran, J.M. *Juran on Planning for Quality*, New York; MacMillan, 1988

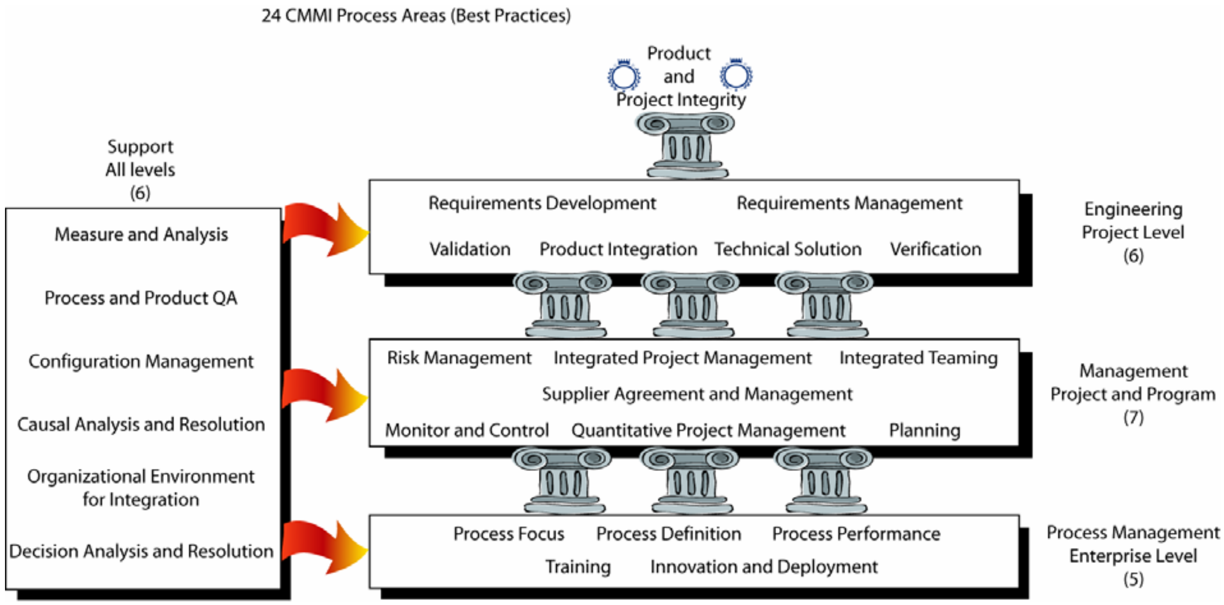


Figure 3 – CMMI Process Categories and Process Areas

As illustrated, a set of best practices is associated with the following categories: engineering, management, support, and process management. For each of the 24 process areas illustrated, there is a set of practices which is required to be performed by the organization to demonstrate a capability and achieve a level of maturity.

Rating Systems:

How is CMMI used? It is a rating system [developed by the Software Engineering Institute] used by Software and Systems development firms to rate how well their organization performs software and systems development. It is used by system's owners, as an evaluation tool, for the selection of a candidate systems development organization. This rating is accomplished in two ways: 1] as a staged representation illustrated in Figures 2 continuous representation illustrated in Figure 3.

Staged Representation:

Staged representation provides a single number 0-5 for an organization that is an indicator of how well they perform software or systems development.

- Level 0 [not on scale] means no processes are documented or followed.
- Level 1 [Initial] Competent people, heroics of the individuals characterize the completion of projects. Processes are known and understood but performance is sometimes unpredictable, poorly controlled, and reactive in execution.
- Level 2 [Repeatable] Basic project management is performed, some configuration, requirements, planning, and control is performed. Practices exist at the project level only and are reactive. Characterized as a good project team, working together. and producing repeatable results from project to project.
- Level 3 [Defined] indicates that the organization has standardized documented processes and follows them. The organization has documented set of processes. They are proactive in the execution of the processes.
- Level 4 [Managed] indicates that the organization has statistical methods for analyzing the processes performed. The processes are measured and controlled.
- Level 5 [Optimizing] Organizations have continual process improvement. The organization has a focus on process.

The Benefits of the staged representation are:

- Pre-determined and proven improvement path
- Focus is on a set of process areas for improvement for attaining the next maturity level
- Provides a single maturity level rating 1-5

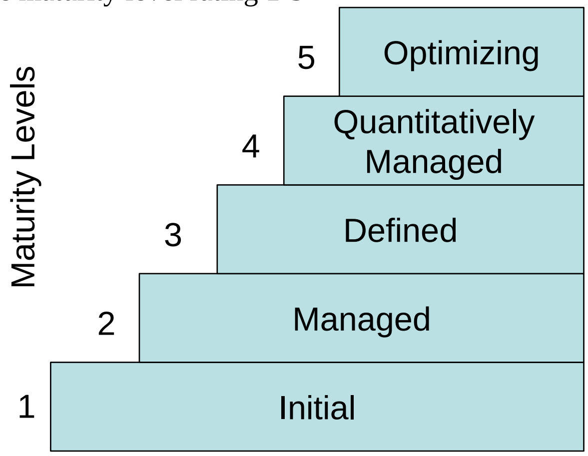


Figure 4 Staged View or Representation of CMMI

Continuous Representation:

Continuous representation is used to focus on specific best practices and is not concerned about an overall rating. In this case, an organization may select and focus on a number of best practices which are critical for the organization. The focus for this example is on performing the 20 best practice areas at a level 2 or higher. The others are not relevant to the organization.

CMMI is a single model with two representations or views: staged and continuous, as discussed above. Organizations choose their representation for process improvement and thereby achieve a level of maturity for their organization.

Organizations may choose their representation depending upon their goals and objectives. For example, a company that provides systems development services may elect to use the staged view; since the results would be a simple number that identifies the organizations maturity level [1-5] as illustrated in Figure 2. Other organizations may elect to use continuous representation to illustrate a "profile" of maturity across the process areas as illustrated in Figure 3. These organizations may be more interested in achieving a profile which addresses specific needs. For example, it may be appropriate for a large agency that develops their own systems to use the continuous view in order to achieve maturity in specific areas. Other areas may not be applicable to them.

It should be noted that, in some cases, the higher levels of maturity are not needed or warranted. So, an organization may elect to stay at a level 2 or 3. The processes involved to achieve the higher levels of maturity [3, 4 and 5] may be too expensive for the return, or the domain of practice does not require it.

Stages of maturity build on each other. A development company at a level 2 CMMI [staged representation] means they have a set of repeatable processes [e.g., estimating the cost for developing software]. If a company matures to a level 3 [staged representation], that implies that they not only have repeatable processes required for level 2, but also have defined and documented processes required for level 3. In the staged representation, each level of competency builds on the previous level.

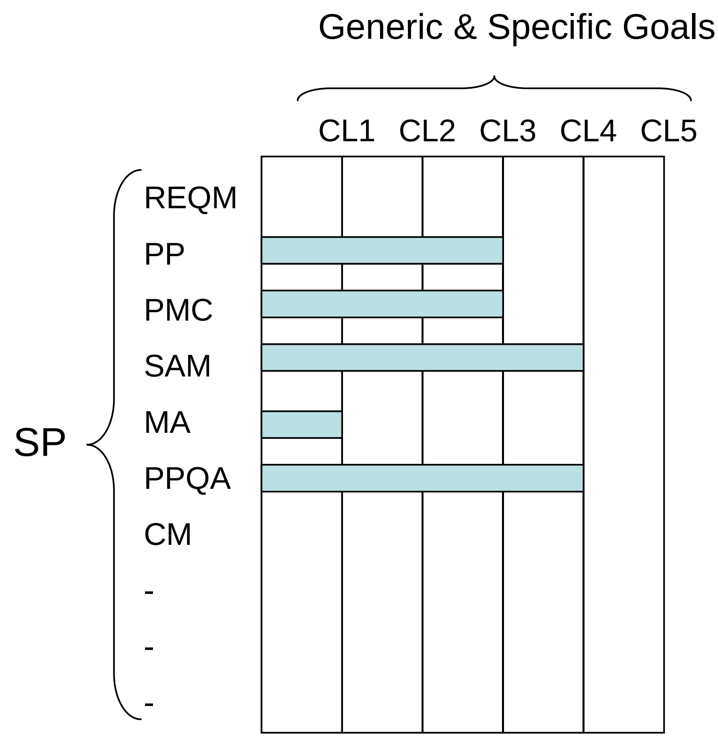


Figure 5 Continuous representation of CMMI

Table 11: Detailed CMMI Process areas and specific practices

CMMI Categories	Capabilities	Capabilities
	Process Area	**Specific Practices**
Engineering		
	Requirements Development	
		Collect Stakeholder Needs
		Elicit Needs
		Develop the Customer Requirements
		Establish Product and Product component Requirements
		Allocate Product-component Requirements
		Identify Interface Requirements
		Establish Operational concepts and scenarios
		Establish a Definition of Required functionality
		Analyze Requirements
		Analyze Requirements to achieve balance
		Validate Requirements
		Validate Requirements with comprehensive methods
	Requirements Management	
		Obtain an understanding of Requirements
		Obtain a commitment to Requirements
		Manage Requirements
		Maintain Bi-directional Traceability of Requirements
		Identify inconsistencies between project work and requirements
	Technical Solutions	
		Develop Alternative Solutions and Selection Criteria
		Develop Detailed Alternative Solutions and Detailed Selection Criteria
		Evolve Operational Concepts and Scenarios
		Select Product-component Solutions
		Design the Product or Product Component
		Establish a Technical Data Package
		Establish Interface Descriptions
		Design Interfaces using Criteria
		Perform Make, Buy or Reuse Analysis
		Implement the Design
		Develop Product Support Documentation
	Product Integration	
		Determine Integration Sequence
		Establish the Product Integration Environment
		Establish Product Integration Procedures and Criteria
		Review Interface Descriptions for Completeness
		Mange Interfaces
		Confirm Readiness of Product Components for Integration
		Assemble Product Components
		Evaluate Assembled Product Components
		Package and Deliver the Product or Product Component

Table 12: Detailed CMMI Process areas and specific practices

	Process Area	Specific Practices
	Verification	
		Select work Products for Verification
		Establish the Verification Environment
		Establish Verification Procedures and Criteria
		Prepare for Peer Reviews
		Conduct Peer Reviews
		Analyze Peer Review Data
		Perform Verification
		Analyze Verification Results and Identify Corrective Action
	Validation	
		Select Products for Validation
		Establish the Validation Environment
		Establish Validation Procedures and Criteria
		Perform Validation
		Analyze Validation Results
Project Management		
	Project Planning	
		Estimate the Scope of the Project
		Establish Estimates of work project and task attributes
		Define Project Lifecycle
		Determine Estimates of effort and cost
		Establish the budget and schedule
		Identify Project Risks
		Plan for Data Management
		Plan for Project Resources
		Plan for Needed knowledge & Skills
		Plan for Stakeholder involvement
		Establish the Project Plan
		Review plans that affect the project
		Reconcile work and resource levels
		Obtain Plan commitment
	Project Monitoring & Control	
		Monitor Project Planning Parameters
		Monitor Commitments
		Monitor Project Risks
		Monitor Data Management
		Monitor Stakeholder Involvement
		Conduct Progress Reviews
		Conduct Milestone Reviews
		Analyze Issues
		Take corrective action
		Manage corrective action
	Supplier Agreement Management	
		Determine Acquisition type
		Select Suppliers
		Establish Supplier Agreements
		Review COTS Products
		Execute the Supplier Agreement
		Accept the acquired product
		Transition Products

Table 5: CMMI Process Areas and Specific Practices (Continued)

	Process Area	Specific Practices
	Integrated Project Management	
		Establish the Project's Defined Process
		Use Organizational Process assets for Planning Project Activities
		Integrate Plans
		Manage the Project Using the Integrated Plans
		Contribute to the Organizational Process Assets
		Manage Stakeholder Involvement
		Manage Dependencies
		Resolve Coordination Issues
		Define Projects Shared Vision Context
		Establish the Project's Shared Vision
		Determine Integrated Team Structure for the Project
		Develop a Preliminary Distribution of Requirements to Integrated Teams
		Establish Integrated Teams
	Risk Management	
		Determine Risk Sources and Categories
		Define Risk Parameters
		Establish a Management Strategy
		Identify risks
		Evaluate, Categorize, and Prioritize Risks
		Develop Risk Mitigation Plans
		Implement Risk Mitigation Plans
	Integrated Teaming	
		Identify Team Tasks
		Identify Needed Knowledge and Skills
		Assign Appropriate Team Members
		Establish A Shared Vision
		Establish a Team Charter
		Define Roles and Responsibilities
		Establish Operating Procedures
		Collaborate Among Interfacing Teams
	Integrated Supplier Management	
		Analyze Potential Sources of Products
		Evaluate and Determine Sources of Products
		Monitor Selected Supplier Processes
		Evaluate Selected Supplier Work Products
		Revise the Supplier Agreement or Relationship
	Quantitative Project Management	
		Establish the Project's Objectives
		Compose the Defined Process
		Select the Sub processes that will be Statistically Managed
		Manage Project Performance
		Select Measures and Analytic Techniques
		Apply Statistical Methods to Understand Variation
		Monitor Performance of the Selected Sub processes
		Record Statistical Management Data

Table 5: CMMI Process Areas and Specific Practices (Continued)

	Process Area	Specific Practices
Support		
	Configuration Management	
		Identify Configuration Items
		Establish a Configuration Management System
		Create or Release Baselines
		Track Change requests
		Control Configuration Items
		Establish configuration Management Records
		Perform Configuration Audits
	Process and Product Quality Assurance	
		Objectively Evaluate Processes
		Objectively Evaluate Work Products and Services
		Communicate and Ensure Resolution of Non-Compliance Issues
		Establish Records
	Measurement & Analysis	
		Establish Measurement Objectives
		Specify Measures
		Specify Data Collection and Storage Procedures
		Specify Analysis Procedures
		Collect Measurement Data
		Analyze Measurement Data
		Store Data and Results
		Communicate Results
	Organizational Environment for Integration	
		Establish Organization's Shared Vision
		Establish an Integrated Work Environment
		Identify IPPD-Unique Skill Requirements
		Establish Leadership Mechanisms
		Establish Incentives for Integration
		Establish Mechanisms to Balance Team and Home Organization Responsibilities
	Decision, Analysis & Resolution	
		Establish Guidelines for Decision analysis
		Establish Evaluation Criteria
		Identify Alternative Solutions
		Select Evaluation Method
		Evaluate Alternatives
		Select Solution
	Causal Analysis & Resolution	
		Select Defect Data for Analysis
		Analyze Causes
		Implement the Action Proposals
		Evaluate the effect of changes
		Record Data

Table 5: CMMI Process Areas and Specific Practices (Continued).

	Process Area	Specific Practices
Process Management		
	Organizational Process Focus	
		Establish Organizational Process needs
		Appraise the Organization's Processes
		Identify the Organization's Process improvement
		Establish Process Action Plans
		Implements Process Actions Plans
		Deploy Organizational Process Assets
		Incorporate Process-related Experiences into the Organizational Process Assets
	Organizational Process Definition	
		Establish Standard Processes
		Establish Life-cycle Model Description
		Establish Tailoring Criteria & Guidelines
		Establish the Organization's Measurement Repository
		Establish the Organization's Process Asset Library
	Organizational Training	
		Establish the Strategic Training Needs
		Determine Which Training Needs are the Responsibility of the Organization
		Establish an Organizational Training tactical Plan
		Establish Training Capability
		Deliver Training
		Establish Training Records
		Assess Training Effectiveness
	Organizational Process Performance	
		Select Processes
		Establish Process-Performance Measures
		Establish Quality and Process-Performance Objectives
		Establish Process Performance Baselines
		Establish Process Performance Models
	Organizational Innovation & Deployment	
		Collect and analyze Improvement Proposals
		Identify and Analyze Innovations
		Pilot Improvements
		Select Improvements for Deployment
		Plan the Deployment
		Manage the Deployment
		Measure Improvement Effects

Appendix C – IPT Relationship Maturity Stages (Adapted from “Smart Acquisition” UK)

	Stage	Beginning	Developing	Performing	High Performing	Excelling
		♦ Them & us	♦ Respect & developing trust	♦ Trust & joint goals lead to results	♦ Resilience to personnel changes, success spreads beyond key areas	♦ Model for others
C O R E	Identify & Understand	♦ Stakeholders identified, but reluctance/ low priority given to making contact with all Stakeholder reps and developing team ♦ Customers & IPT do not understand or value each others goals	♦ Customers-IPT identified and mapped from desk officer to leaders, with a view and a determination to understand each other’s goals ♦ Positive dialogue and regular interaction to understand goals & requirements and develop plans	♦ All customers & IPT requirements understood across the team ♦ All goals are aligned to assist whole team ♦ Actions in place to meet other goals	♦ System for managing differing requirements of customers ♦ Shared ownership of goals ♦ System for dealing with evolving customer needs ♦ Easily recognizable, regular shared successes	♦ “Working together as one team” is reality, not mere assertion ♦ Goals developed together from outset ♦ Changing needs of customers easily accommodated ♦ Approach leads to benefits across program- a model for others
	Processes	♦ Ineffective team identification ♦ Requirement capture limited to primary URD/ SRD formulation ♦ No process to identify/develop other requirements ♦ No record of dialogue/ tasking	♦ Customers & IPT identified ♦ Mapping of URD/ SRD ♦ Process Owners in place ♦ Needs analysis and requirement capture process, but lack of verification that the process is being used and it's effectiveness	♦ Process in place and functioning, capturing and managing stakeholders needs ♦ System promotes and manages regular team communication and understanding ♦ Process effectiveness assessed and reviewed.	♦ System manages changing needs of Customers & IPT ♦ Communication evolves to meet changing needs for information	♦ System collects intelligence about future changes and matches with industrial opportunities ♦ Manages open dialogue with all stakeholders (actively engaging industry)
	Relationship (who is involved)	♦ Them and us ♦ Customers and IPT not engaged at all levels ♦ Individuals do not know who to talk to	♦ Endeavour to have regular communication (possibly not at appropriate levels) ♦ Priority placed on respect & developing trust	♦ Trust and joint goals lead to results in key areas which builds confidence ♦ Partnership at senior level, others aware ♦ Communicate when milestones achieved or problem occurs	♦ Trust is resilient to changes in personnel. ♦ Majority of team involved and contributing ♦ Communicate regularly to discuss progress and determine way forward	♦ Whole team involved, everybody aware of what's going on. ♦ Partnership ethos ♦ Model for others
S U P P O R T	Parent / host Organisation & Policy owner	♦ Plays no part in stimulating or challenging team to improve relationships. ♦ Little interest/ low priority	♦ Organization challenges performance on ad hoc basis ♦ Offers little help in managing relations with customers.	♦ Organizational level interventions assist in common problem areas ♦ Organization influences key senior players to open doors	♦ Peer system actively assists IPTs to share experiences & practices ♦ Practices that improve & spread performance across program	♦ Team regularly engages with parent org and wider groups for spreading best practice and encouraging action in other teams
	Meetings (IPT/Customer)	♦ Project progress mtng/One to One do not meet enough ♦ Membership incomplete ♦ Members not engaged ♦ Goals not aligned	♦ Project progress mtng/One to One meets regularly ♦ Includes all Customers and other Stakeholders if appropriate ♦ All requirements identified	♦ Project progress mtng/One to One convened as necessary ♦ Builds understanding ♦ Members pro-active ♦ Appreciate difficulties of others	♦ Effective team ♦ Joint objectives ♦ Helping each other to solve problems	♦ Recognized model for others ♦ Customer and IPT speak with one voice
	Customer Supplier Agreement	♦ No CSA	♦ Key URs agreed ♦ Draft CSA but incomplete or unused	♦ Developing as a negotiation tool ♦ Documents key agreements	♦ A useful, effective management tool. Not a device for apportioning blame	♦ Flexible and valuable CSA
	Risks	♦ Performance, Time, Cost (PTC) at risk ♦ Lack of success discourages ♦ Little benefit to team	♦ Team lacks common purpose ♦ Too few people involved, very little agreement	♦ On track for PTC but change of one or two key people disturbs relationship and plans	♦ Underlying risk of disruption if key people change	♦ Complacency
	Benefits	♦ No change is comfortable	♦ Shared goals and plans ♦ Customers requirements developed ♦ Key URs agreed with robust plans ♦ More productive relationship	♦ Team confidence in PTC targets ♦ Understanding goals & constraints ♦ Improved Program delivery ♦ Success improves relationship	♦ Team confidence in exceeding targets ♦ Program recognized as model of SMART achievement, savings declared	♦ Capability benefits spread to other program ♦ Working with others to develop and deploy Best Practice - provides integrated, thought out solutions

Appendix D: Department of Finance Interview Notes

Attendees: Greg Loe (DOF), Lori Knott (Caltrans IT - PPMD), Bill Worden (Caltrans IT - PPMD), Reza Navai (Caltrans Planning), Darlene Tigner (Caltrans Planning), Mike Krueger (ASE Consulting), Ron Ice (Ice and Associates)

The meeting began with a brief presentation that covered Systems Engineering, related initiatives at Caltrans, and the DOF-related findings of this Systems Engineering Evaluation Project. The briefing was followed by an active, but positive, round table discussion.

The State Legislature and the FSR Timeline

Greg pointed out that the state legislature will not entertain budget change requests if they are not supported by the current FSR process. The legislature would have to concur with any substantial change in that process. The legislature requires FSRs to be created per the State Acquisition Manual (SAM). The FSR must be received before the project funding request. There have been numerous initiatives that have attempted to facilitate the FSR process, but the state budget process really drives the FSR process and the associated delays. Essentially, the legislature wants to have a role in IT project selection. Greg described the following timeline for IT projects:

- FSRs are submitted to DOF once a year in July.
- The associated budget changes are identified in early fall. Project “approval” occurs in the fall, but it is kept a secret until the Governor’s budget is issued.
- The Governor’s budget is issued in early January.
- Following negotiations, the budget is approved and signed some time in July.

Thus, a one year delay is built into the timeline between the time FSRs are submitted to DOF in July and the earliest that spending authority can be received for the project the following July. Fundamentally changing this timeline and expediting the process would require lobbyists to convince the legislature to reduce or delegate their project-by-project budgetary control of larger IT projects. Note that this timeline only applies to IT projects; traditional transportation projects are programmed under the capital program where the California Transportation Commission programs the entire budget for the transportation program.

Reducing the Impact of One Year Delay

DOF realizes that the process is far from optimal and does what it can to facilitate the process. While the FSRs are officially due in July, DOF tries to work with Caltrans and accommodate later FSRs that are submitted in October, November, (or even December?). In order to mitigate the risk of hardware/software evolution during the one year budget cycle delay, DOF prefers that FSRs include the business case and define the business requirements and allow vendors to specify the hardware/software solution after the FSR is approved, rather than lock into a hardware/software solution in the FSR.

Dispelling Myths About the FSR Process

California Department of Finance
Systems Engineering Process Data Collection Meeting
Date March 3, 2006 - Time: 1:00pm – 2:00pm

During our data collection effort, we collected many comments reflecting commonly held perceptions within Caltrans regarding the FSR process and DOF oversight requirements. These comments and perceptions were discussed.

Perception: The FSR is a new requirement.
Discussion: The State Administrative Manual (SAM) has always required a feasibility study for IT projects. Smaller projects (less than $500k) also require a feasibility study, but DOF approval is not required since the funding requirements are within Caltrans departmental budget authority. Note that an FSR is required regardless of whether the project is funded with local, state, or federal funds since it is spending authority, not budgets, which are approved. The legislature grants spending authority for all IT projects, whether the project funds are from federal, state, or local funding sources.

Perception: The FSR must be done at the beginning of project development
Discussion: Since the FSR is developed early in the project development process at Caltrans and significant delays are typical, project costs are very difficult to estimate accurately. Essentially, this means that projects become design to cost projects and user requirements must be sacrificed to meet budget constraints established in the FSR. This forces Caltrans into a mode where they "plan to budget" for each project, rather than "budget to plan".

In reality, Caltrans has considerable latitude in establishing when the FSR is prepared in the project development process. An FSR is not required to do analysis or design, so the FSR could be generated after the analysis and design steps in the systems engineering process. The only limitation is that the FSR must be submitted and approved before operational hardware/software is developed or procured and installed. Also, Caltrans must be able to fund any analysis/design that is performed prior to the FSR. Producing the FSR later in the process would yield more accurate cost estimates and allow the output of the analysis and design steps to be referenced to satisfy FSR documentation requirements.

R&D projects were discussed as an example of projects that perform analysis without an FSR. These projects are ok with DOF as long as operational hardware/software is not installed as a result of the "R&D" project. It would even be ok to procure hardware/software tools that are required to support the analysis/research without an FSR, but the expectation is that these would be relatively small-scale procurements that are within Caltrans budget authority. Caltrans can choose when the FSR is generated, as long as it occurs before IT hardware (servers, switches, routers, etc.) and software is procured.

Perception: DOF will only approve projects that will yield hard Person Year (PY) savings.
Discussion: Hard PY savings are not required for project approval; broader economic/social benefits are also acceptable justification for a project. Greg related that he is about to recommend approval of a $40M project based on its projected service to the public, even though the project does not show agency PY savings. The general requirement is to build a business case for the project. If the project claims labor savings, then PY savings should be specified.

Ultimately, project approval does rely on the fiscal environment. DOF may appear to be the "bad guy" but is merely implementing the administration's fiscal policy.

Perception: DOF requires the Project Manager to be from the IT Division

Discussion: DOF focuses on the qualifications of the project manager. DOF expects the project managers to have relevant experience. For example, the project manager for a software-intensive project should have experience in managing software acquisition. DOF does not comment on the internal organization of the department, so the experienced individual can come from any division within Caltrans. It would also be acceptable to manage projects with a management team that includes a person with IT/software procurement experience and a person with operational experience that would represent user needs. While DOF doesn't look at the division/organization, but the experience and credentials of the project manager, the internal Caltrans review and signatures may require participation by specific divisions. The Caltrans CIO must sign off on the FSR.

Perception: The DOF approval cycle is lengthy
Discussion: The time that is required for DOF to make a recommendation on a project is not the largest part of the delay. For example, the reversible lanes project FSR was actually approved quickly by DOF once it was generated. As noted above, delays are inherent in the process due to the budget cycle, which is largely beyond Caltrans and DOF control. When a project is not approved, there are often other issues. For example, the problem with CATMS was that it did not have a funding plan – an FSR will not be approved without identified funding in the budget for the project.

The internal FSR signature cycle within Caltrans can also be lengthy, requiring 30, 45 or more days for the management chain up through the deputy director and the CIO to sign off on the FSR before it goes to DOF. For example, the FSR for the $300k WSVS project has been collecting signatures within Caltrans since October.

Perception: Special Project Reports (SPRs) are just as onerous as FSRs
Discussion: Neither Greg nor Lori agreed with this. SPRs may be very short and succinct and focus on describing the deviation and rationale for the deviation. For example, a recent SPR was four pages in length.

FSR Content Requirements

The group compared the systems engineering process and associated FHWA requirements with the required FSR content. In general, Greg felt that the FSR content requirements would be satisfied by the output of the systems engineering process identified in the presentation – most of the FHWA Systems Engineering Analysis requirements would be reflected in FSR content. The FSR is really the result of the systems engineering analysis with a signature page at the front and economic justification forms at the end.

The basic content of the FSR is what is required, not a specific document format, outline, or title. Greg personally would not have a problem with receiving systems engineering documents with a cover sheet/cross reference in lieu of an FSR as long as it satisfies the intent – to prove that you know what to do, you know how to go about it, and there is a sound business case underlying the project.

One concern with using a collection of documents to satisfy FSR requirements is the volume of documentation that would have to be reviewed. Brevity is appreciated. A 20 page FSR would be great, with elaboration in the other documents. The FSR could be viewed as an executive overview/plan that is supported by the referenced project documents.

There is precedent for DOF to accept another equivalent report instead of the FSR. For welfare projects, DOF accepts the Implementation Advance Planning Document (IAPD), a document that is required for federal project approval, instead of the FSR. *(The Office of System Integration has an excellent web site at http://www.bestpractices.cahwnet.gov/ that describes how that organization integrates the IAPD/FSR into its process. It is interesting to note that the FSR (or IAPD) is not generated until after an RFP has been generated and a contractor has been selected in that documented process.. The contractor's bid is used to generate an accurate cost estimate that is used in the FSR/IAPD. This is much later in the process that the approach used at Caltrans. There is another Planning Advance Planning Document (PAPD) that is developed early in this process.)*

Supporting Incremental Projects

Systems that are developed incrementally with a number of projects that are implemented over a period of several years may be approved by developing an initial FSR and then developing an SPR for each increment. A single Budget Change Proposal (BCP) could be created for the multi-year project or a BCP could be submitted that covers the first year.

Next Steps

Greg agreed to participate in the review of our final report.